Human polypeptides causing or leading to the killing of cells including lymphoid tumor cells

5 ## Application Information

This application is a continuation-in-part of International Application No. PCT/US01/15625, filed on May 14, 2001, which designated the U.S. and will be published under PCT Article 21(2) in English, and which claims priority to EP 00110065.0, filed on May 12, 2000, the entire contents of which are incorporated by reference herein.

10 ## Background of the Invention

Every mammalian species, which has been studied to date, carries a cluster of genes coding for the so-called major histocompatibility complex (MHC). This tightly linked cluster of genes code for surface antigens, which play a central role in the development of both humoral and cell-mediated immune responses. In humans the

15 products coded for by the MHC are referred to as Human Leukocyte Antigens or HLA. The MHC-genes are organized into regions encoding three classes of molecules, class I to III.

Class I MHC molecules are 45 kD transmembrane glycoproteins, noncovalently associated with another glycoprotein, the 12 kD beta-2 microglobulin (Brown et al., 1993).

20 The latter is not inserted into the cell membrane, and is encoded outside the MHC. Human class I molecules are of three different isotypes, termed HLA-A, -B, and -C, encoded in separate loci. The tissue expression of class I molecules is ubiquitous and codominant. MHC class I molecules present peptide antigens necessary for the activation of cytotoxic T-cells.

25 Class II MHC molecules are noncovalently associated heterodimers of two transmembrane glycoproteins, the 35 kD α chain and the 28 kD β chain (Brown et al., 1993). In humans, class II molecules occur as three different isotypes, termed human leukocyte antigen DR (HLA-DR), HLA-DP and HLA-DQ. Polymorphism in DR is restricted to the β chain, whereas both chains are polymorphic in the DP and DQ isotypes.

30 Class II molecules are expressed codominantly, but in contrast to class I, exhibit a

restricted tissue distribution: they are present only on the surface of cells of the immune system, for example dendritic cells, macrophages, B lymphocytes, and activated T lymphocytes. They are also expressed on human adrenocortical cells in the zona reticularis of normal adrenal glands and on granulosa-lutein cells in corpora lutea of normal ovaries (Kahoury et al., 1990). Their major biological role is to bind antigenic peptides and present them on the surface of antigen presenting cells (APC) for recognition by CD4 helper T (Th) lymphocytes (Babbitt et al., 1985). MHC class II molecules can also be expressed on the surface of non-immune system cells, for example, cells that express MHC class II molecules during a pathological inflammatory response. These cells may include synovial cells, endothelial cells, thyroid stromal cells and glial cells.

Class III MHC molecules are also associated with immune responses, but encode somewhat different products. These include a number of soluble serum proteins, enzymes and proteins like tumor necrosis factor or steroid 21-hydroxylase enzymes. In humans, class III molecules occur as three different isotypes, termed Ca, C2 and Bf (Kuby, 1994).

Since Th cell activation is a crucial event of the initiation of virtually all immune responses and is mediated through class II molecules, class II MHC offers itself as a target for immunomodulation (Baxevanis et al., 1980; Rosenbaum et al., 1981; Adorini et al., 1988). Besides peptide presentation, class II molecules can transduce various signals that influence the physiology of APC. Such signals arise by the interaction of multiple class II molecules with an antibody or with the antigen receptor of Th cells (Vidovic et al., 1995a; Vidovic et al., 1995b), and can induce B cell activation and immunoglobulin secretion (Cambier et al., 1991; Palacios et al., 1983), cytokine production by monocytes (Palacios, 1985) as well as the up-regulation of co-stimulatory (Nabavi et al., 1992) and cell adhesion molecules (Mourad et al., 1990).

There is also a set of observations suggesting that class II ligation, under certain conditions, can lead to cell growth arrest or be cytotoxic. Ligation under these conditions is the interaction of a polypeptide with a class II MHC molecule. There is substantial contradiction about the latter effects and their possible mechanisms. Certain authors claim that formation of a complex of class II molecules on B cells leads to growth inhibition (Vaickus et al., 1989; Kabelitz et al., 1989), whereas according to others class II complex formation results in cell death (Vidovic et al., 1995a; Newell et al., 1993; Truman et al.,

1994; Truman et al., 1997; Drenou et al., 1999). In certain experimental systems, the phenomenon was observed with resting B cells only (Newell et al., 1993), or in other systems with activated B cells only (Vidovic et al., 1995a; Truman et al., 1994).

5   Based on these observations, anti-class II monoclonal antibodies (mAbs) have been envisaged for a number of years as therapeutic candidates. Indeed, this proposal has been supported by the beneficial effect of mouse-derived anti-class II mAbs in a series of animal disease models (Waldor et al., 1983; Jonker et al., 1988; Stevens et al., 1990; Smith et al., 1994; Vidovic & Torral, 1998; Vidovic & Laus, 2000).

10   Despite these early supporting data, to date no anti-MHC class II mAb of human composition has been described that displays the desired cytotoxic and other biological properties which may include affinity, efficiency of killing and selectivity. Indeed, despite the relative ease by which mouse-derived mAbs may be derived, work using mouse-derived mAbs has demonstrated the difficulty of obtaining an antibody with the desired biological properties. For example, significant and not fully understood differences were

15   observed in the T cell inhibitory capacity of different murine anti-class II mAbs (Naquet et al., 1983). Furthermore, the application of certain mouse-derived mAbs *in vivo* was associated with unexpected side effects, sometimes resulting in death of laboratory primates (Billing et al., 1983; Jonker et al., 1991).

It is generally accepted that mouse-derived mAbs (including chimeric and so-called

20   "humanized" mAbs) carry an increased risk of generating an adverse immune response (Human anti-murine antibody – HAMA) in patients compared to treatment with a human mAb (for example, Vose et al, 2000; Kashmiri et al., 2001). This risk is potentially increased when treating chronic diseases such as rheumatoid arthritis or multiple sclerosis with any mouse-derived mAb or where regular treatment may be required, for example in

25   the treatment of certain cancers; prolonged exposure of the human immune system to a non-human molecule often leads to the development of an adverse immune reaction. Furthermore, it has proven very difficult to obtain mouse-derived antibodies with the desired specificity or affinity to the desired antigen (Pichla et al. 1997). Such observation may significantly reduce the overall therapeutic effect or advantage provided by mouse-

30   derived mAbs. Examples of disadvantages for mouse-derived mAbs may include the following. First, mouse-derived mAbs may be limited in the medical conditions or length

of treatment for a condition for which they are appropriate. Second, the dose rate for mouse-derived mAbs may need to be relatively high in order to compensate for a relatively low affinity or therapeutic effect, hence making the dose not only more severe but potentially more immunogenic and perhaps dangerous. Third, such restrictions in suitable

5   treatment regimes and high-dose rates requiring high production amounts may significantly add to the cost of treatment and could mean that such a mouse-derived mAb be uneconomical to develop as a commercial therapeutic. Finally, even if a mouse mAb could be identified that displayed the desired specificity or affinity, often these desired features are detrimentally affected during the "humanization" or "chimerization"

10   procedures necessary to reduce immunogenic potential (Slavin-Chiorini et al., 1997). Once a mouse-derived mAb has been "humanized" or chimerized, then it is very difficult to optimize its specificity or affinity.

The art has sought over a number of years for anti-MHC class II mAbs of human composition that show biological properties suitable for use in a pharmaceutical

15   composition for the treatment of humans. Workers in the field have practiced the process steps of first identifying a mouse-derived mAb, and then modifying the structure of this mAb with the aim of improving immunotolerance of this non-human molecule for human patients (for further details, see Jones et al., 1986; Riechmann et al., 1988; Presta, 1992). This modification is typically made using so-called "humanization" procedures or by

20   fabricating a human-mouse chimeric mAb. Other workers have attempted to identify human antibodies that bind to human antigens having desired properties within natural repertoires of human antibody diversity. For example, by exploring the fetal-tolerance mechanism in pregnant women (Bonagura et al., 1987) or by panning libraries of natural diversities of antibodies (Stausbøl-Grøn et al., 1996; Winter et al., 1994). However, to date

25   no anti-MHC class II mAb of human composition has been described that displays the desired biological properties of cytotoxicity, selectivity, specificity, low immunogenicity and affinity.

For therapeutic purposes a polypeptide reacting with most or at least many of the common allelic forms of a human class II MHC molecule would be desirable – e.g., to

30   enable its use in diverse patient populations. Moreover, the candidate polypeptide should be cytotoxic to a wide range of lymphoid tumors, and preferably is cytotoxic by way of a

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mechanism common to such a range of tumor cells. To allow for a wide range of possible applications, the polypeptide desired should mediate its cytotoxic effect without the dependence on further components of the immune system. For therapeutic purposes, most patients receive for the treatment of, e.g. cancer, standard chemo- or radiotherapy. Most of these treatments leave the patient immunocompromised. Any additional treatment that relies on an intact immune system is therefore likely to fail. The underlying problem is further demonstrated in humans who suffer from a disease that destroys the immune system, e.g. HIV. Opportunistic infections and malignant transformations are able to escape the immune-surveillance and cause further complications.

Summary of the Invention

One aspect of the present invention relates to a composition including a polypeptide comprising at least one antibody-based antigen-binding domain of human composition with binding specificity for an antigen expressed on the surface of a human cell, wherein treating cells expressing the antigen with a multivalent polypeptide having two or more of said antigen binding domains causes or leads to killing of the cells in a manner where neither cytotoxic entities nor immunological mechanisms are needed for killing. In certain preferred embodiments the antigen is an MHC antigen, preferably an MHC class II antigen, such as DR/DP/DQ or DR. For instance, in certain preferred embodiments, the subject compositions include a polypeptide comprising at least one antibody-based antigen-binding domain which binds to human HLA-DR with a K_d of 1 μM, 100 nM, 10 nM or even 1 nM or less.

Another aspect of the present invention provides a composition including a multivalent polypeptide comprising a plurality of antibody-based antigen-binding domains of human composition with binding specificity for human HLA-DR. Treating cells expressing HLA-DR with the multivalent polypetide causes or leads to killing of the cell in a manner where neither cytotoxic entities nor immunological mechanisms are needed for killing. In certain preferred embodiments, the said antigen-binding domains individually bind to the human HLA-DR with a K_d of 1 μM, 100 nM, 10 nM or even 1 nM or less. In certain preferred embodiments, the multivalent polypeptide has an EC_{50} of 100 nM, 10 nM or even 1 nM or less for killing activated lymphoid cells, transformed cells and/or lymphoid tumor cells.

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Still another aspect of the present invention provides a composition including a polypeptide comprising at least one antibody-based antigen-binding domain that binds to human HLA-DR with a K_d of 1 μM, 100 nM, 10 nM or even 1 nM or less, the antigen-binding domain being isolated by a method which includes isolation of human VL and VH domains from a recombinant antibody library by ability to bind to at least one epitope of human HLA-DR. Treating a cell expressing HLA-DR with a multivalent polypeptide having two or more of the antigen binding domains causes or leads to killing of the cells in a manner where neither cytotoxic entities nor immunological mechanisms are needed for killing. In certain embodiments, the method for isolating the antigen-binding domain includes the further steps of: a) generating a library of variants of at least one of the CDR1, CDR2 and CDR3 sequences of one or both of the VL and VH domains, and, b) isolation of VL and VH domains from the library of variants by ability to bind to human HLA-DR with a K_d of 1 μM or less.

In certain preferred embodiments, the composition of the present invention can be characterized as including multivalent polypeptides having an EC_{50} for killing transformed cells at least 5-fold lower than the EC_{50} for killing normal cells, and even more preferably at least 10-fold, 100-fold and even 1000-fold less than for killing normal cells.

In certain preferred embodiments, the composition of the present invention are characterized as including multivalent polypeptides having an EC_{50} for killing activated cells at least 5-fold lower than the EC_{50} for killing unactivated cells, and even more preferably at least 10-folded, 100-fold and even 1000-fold less than for killing unactivated cells.

In certain preferred embodiments, the composition of the present invention are characterized as including multivalent polypeptides having an EC_{50} of 50 nM or less for killing transformed cells, and even more preferably an EC_{50} of less than 10 nM, 1 nM and even 0.1 nM. In certain embodiments, the subject multivalent polypeptides have an EC_{50} for killing activated lymphoid cells, transformed cells and/or lymphoid tumor cells of 100 nM, 10 nM or even 1 nM or less.

In certain embodiments, the subject compositions including multivalent polypeptides that selectively kill activated lymphoid cells. For example, such multivalent forms of the subject compositions can be used to kill activated lymphoid cells are

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lymphoid tumor cells representing a disease selected from B cell non-Hodgkin lymphoma, B cell lymphoma, B cell acute lymphoid leukemia, Burkitt lymphoma, Hodgkin lymphoma, hairy cell leukemia, acute myeloid leukemia, T cell lymphoma, T cell non-Hodgkin lymphoma, chronic myeloid leukemia, chronic lymphoid leukemia, and multiple myeloid leukemia. Exemplary activated lymphoid tumor cells which can be killed include PRIESS, GRANTA-519, KARPAS-422, KARPAS-299, DOHH-2, SR-786, MHH-CALL-4, MN-60, BJAB, RAJI, L-428, HDLM-2, HD-MY-Z, KM-H2, L1236, BONNA-12, HC-1, NALM-1, L-363, EOL-1, LP-1, RPMI-8226, and MHH-PREB-1 cell lines. In certain preferred embodiments, the subject compositions have an EC_{50} of 100 nM or less, and preferably less than 10 nM or even 1 nM, for killing at least one of B cell lymphoma cells and T cell lymphoma cells selected from the list of KARPAS-422, DOHH-2, SR-7, MHH-CALL-4, MN-60, HD-MY-Z, NALM-1 and LP-1. In certain instances, to effect cell killing, the target cells may require further activation or pre-activation, such as by by incubation with Lipopolysaccharide (LPS, 10 µg/ml), Interferon-gamma (IFN-γ, Roche, 40 ng/ml) and/or phyto-hemagglutinin (PHA, 5 µg/ml) to name but a few.

In certain embodiments, the multivalent forms of the subject compositions can be used to kill non-lymphoid cells that express MHC class II molecules.

In certain embodiments, one or more of the antigen binding domains of the subject compositions bind to the β-chain of HLA-DR, e.g., the antigen-binding domain binds to the first domain of the β-chain of HLA-DR.

In certain other embodiments, one or more of the antigen binding domains of the subject compositions bind to the α-chain of HLA-DR, e.g., the antigen-binding domain binds to the first domain of the α-chain of HLA-DR.

In certain preferred embodiments, the antigen binding domain(s) of the subject compositions bind to one or more HLA-DR types selected from the group consisting of DR1-0101, DR2-15021, DR3-0301, DR4Dw4-0401, DR4Dw10-0402, DR4Dw14-0404, DR6-1302, DR6-1401, DR8-8031, DR9-9012, DRW53-B4*0101 and DRW52-B3*0101. In preferred embodiments, the antigen binding domains of the subject compositions provide broad-DR reactivity, that is, the antigen-binding domain(s) of a given composition binds to epitopes on at least 5 different of said HLA-DR types. In certain embodiments, the antigen binding domain(s) of a polypeptide(s) of the subject compositions binds to a

plurality of HLA-DR types as to bind to HLA-DR expressing cells for at least 60 percent of the human population, more preferably at least 75 percent, and even more preferably 85 percent of the human population.

In certain embodiments, the antigen-binding domains of the subject compositions include a combination of a VH domain and a VL domain, wherein said combination is found in one of the clones taken from the list of MS-GPC-1, MS-GPC-6, MS-GPC-8, MS-GPC-10, MS-GPC-8-1, MS-GPC-8-6, MS-GPC-8-9, MS-GPC-8-10, MS-GPC-8-17, MS-GPC-8-18, MS-GPC-8-27, MS-GPC-8-6-2, MS-GPC-8-6-19, MS-GPC-8-6-27, MS-GPC-8-6-45, MS-GPC-8-6-13, MS-GPC-8-6-47, MS-GPC-8-10-57, MS-GPC-8-27-7, MS-GPC-8-27-10 and MS-GPC-8-27-41.

In certain embodiments, the antigen-binding domains of the subject compositions include a combination of HuCAL VH2 and HuCAL Vλ1, wherein the VH CDR3, VL CDR1 And VL CDR3 is found in one of the clones taken from the list of MS-GPC-1, MS-GPC-8, MS-GPC-10, MS-GPC-8-1, MS-GPC-8-6, MS-GPC-8-9, MS-GPC-8-10, MS-GPC-8-17, MS-GPC-8-18, MS-GPC-8-27, MS-GPC-8-6-2, MS-GPC-8-6-19, MS-GPC-8-6-27, MS-GPC-8-6-45, MS-GPC-8-6-13, MS-GPC-8-6-47, MS-GPC-8-10-57, MS-GPC-8-27-7, MS-GPC-8-27-10 and MS-GPC-8-27-41.

In a further preferred embodiment, the antigen-binding domain is modified compared to a parental antigen-binding domain of the present invention by addition, deletion and/or substitution of amino acid residues, while maintaining the properties according to the present invention, or improving one or more of said properties, of said parental antigen-binding domain. This may include, but is not limited to, the modification of a nucleic acid sequence encoding a parental antigen-binding domain for cloning purposes, the modification of CDR regions in order to improve or modify antigen-binding affinity and/or specificity, including the exchange of one or more CDR sequences of a parental antigen-binding domain by corresponding CDR sequences from one or more different antigen-binding domains, and the addition of peptide sequences for detection and/or purification purposes. It is well within the scope of one of ordinary skill in the art to identify positions in a given parental antigen-binding domain where an addition, deletion and/or substitution should occur, to design and pursue the approach to achieve said addition, deletion and/or substitution, and to test or assay whether the modified antigen-

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binding domain has maintained the properties of, or exhibits one or more improved properties compared to, the parental antigen-binding domain. Furthermore, one of ordinary skill would be able to design approaches where collections or libraries of modified antigen-binding domains are designed, constructed and screened to identify one or more

5 modified antigen-binding domain which have maintained the properties, or exhibit one or more improved properties compared to the parental antigen-binding domain. In one example, the first amino acid residue of a HuCAL VH domain comprised in any antigen-binding domain or the present invention, which is either E or Q depending on the expression construct, may be exchanged by Q or E, respectively. Preferred regions to

10 optimize an antigen-binding domain by designing, constructing and screening collections or libraries of modified antigen-binding domains according to the present invention comprise the CDR regions, and most preferably CDR3 of VH and VL, CDR1 of VL and CDR2 of VH domains.

In certain embodiments, the antigen-binding domains includes a combination of

15 HuCAL VH2 and HuCAL Vλ1, wherein the VH CDR3 sequence is taken from the consensus CDR3 sequence:

XXXXRGXFDX (SEQ ID No. 1)

wherein each X independently represents any amino acid residue; and/or,

wherein the VL CDR3 sequence is taken from the consensus CDR3 sequence:

20 QSYDXXXX (SEQ ID No. 2)

wherein each X independently represents any amino acid residue. For instance, the VH CDR3 sequence can be SPRYGAFDY (SEQ ID No. 3) and/or the VL CDR3 sequence can be QSYDLIRH (SEQ ID No. 4) or QSYDMNVH (SEQ ID No. 5).

In certain embodiments, the antigen-binding domains of the subject antigen-

25 binding domain competes for antigen binding with an antibody including a combination of HuCAL VH2 and HuCAL Vλ1, wherein the VH CDR3 sequence is taken from the consensus CDR3 sequence:

XXXXRGXFDX (SEQ ID No. 1)

each X independently represents any amino acid residue; and/or,

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the VL CDR3 sequence is taken from the consensus CDR3 sequence:

QSYDXXXX (SEQ ID No. 2)

each X independently represents any amino acid residue. For instance, the VH CDR3 sequence can be SPRYGAFDY (SEQ ID No. 3) and/or the VL CDR3 sequence can be QSYDLIRH (SEQ ID No. 4) or QSYDMNVH (SEQ ID No. 5).

In certain preferred embodiments, the antigen-binding domain includes a VL CDR1 sequence represented in the general formula:

SGSXXNIGXNYVX (SEQ ID No. 6)

wherein each X independently represents any amino acid residue. For instance, the CDR1 sequence is SGSESNIGNNYVQ (SEQ ID No. 7).

In preferred embodiments, the mechanism of killing by multivalent forms of the subject compositions involves an innate pre-programmed process of said cell. For instance, the killing is non-apoptotic. Killing by the subject compositions can be dependent on the action of non-caspase proteases, and/or killing which cannot be inhibited by zVAD-fmk or zDEVD-fmk.

In certain preferred embodiments, the antibody-based antigen-binding domain is part of a multivalent polypeptide including at least a F(ab')$_2$ antibody fragment or a mini-antibody fragment.

In certain preferred embodiments, the antibody-based antigen-binding domain is part of a multivalent polypeptide comprising at least two monovalent antibody fragments selected from Fv, scFv, dsFv and Fab fragments, and further comprises a cross-linking moiety or moieties.

In certain preferred embodiments, the antibody-based antigen-binding domain is part of a multivalent polypeptide comprising at least one full antibody selected from the antibodies of classes IgG$_1$, 2a, 2b, 3, 4, IgA, and IgM.

In certain preferred embodiments, the antibody-based antigen-binding domain is part of a multivalent polypeptide is formed prior to binding to said cell.

In certain preferred embodiments, the antibody-based antigen-binding domain is part of a multivalent polypeptide is formed after binding to said cell.

In certain preferred embodiments, the antigen binding sites are cross-linked to a polymer.

Another aspect of the present invention provides a nucleic acid comprising a coding sequence for an antigen-binding domain, such as those antigen binding domains described above, or a multivalent polypeptide thereof. For example, in certain embodiments, the nucleic acid includes a coding sequence for a polypeptide comprising at least one antibody-based antigen-binding domain of human composition with binding specificity for an antigen expressed on the surface of a human cell, wherein treating cells expressing the antigen with a multivalent form of the polypeptide causes or leads to killing of said cell in a manner where neither cytotoxic entities nor immunological mechanisms are needed for killing. In certain embodiments, the nucleic acid includes a coding sequence for a polypeptide comprising at least one antibody-based antigen-binding domain which binds to at least one epitope of human HLA-DR with a K_d of 1 µM, 100 nM, 10 nM or even 1 nM or less.

In certain embodiments, the nucleic acid includes a coding sequence for a polypeptide comprising a plurality of antibody-based antigen-binding domains of human composition with binding specificity for human HLA-DR, wherein treating a cell expressing HLA-DR with the multivalent polypeptide causes or leads to killing of the cell in a manner where neither cytotoxic entities nor immunological mechanisms are needed for killing. In preferred embodiments, the antigen-binding domains individually bind to epitopes on the human HLA-DR with a K_d of 1 µM, 100 nM, 10 nM or even 1 nM or less.

In certain embodiments, the nucleic acid includes a coding sequence for a multivalent polypeptide comprising a plurality of antibody-based antigen-binding domains of human composition with binding specificity for human HLA-DR, wherein treating a cell expressing HLA-DR with said multivalent polypeptide causes or leads to killing of said cell in a manner where neither cytotoxic entities nor immunological mechanisms are needed for said cell killing. Preferably, the multivalent polypeptide has an EC_{50} for killing activated lymphoid cells, transformed cells and/or lymphoid tumor cells of 100 nM, 10 nM or even 1 nM or less.

Another aspect of the invention provides a vector comprising the coding sequence of any one of the subject nucleic acids, e.g., as described above, and a transcriptional regulatory sequence operably linked thereto.

Still another aspect of the present invention provides a host cell harboring at least one subject nucleic acids or the subject vector. Another aspect of the present invention provides a method for the production of a multivalent composition that causes or leads to killing of cells in a manner where neither cytotoxic entities nor immunological mechanisms are needed to cause or lead to said killing comprising culturing the host cells under conditions wherein the nucleic acid is expressed either as a polypeptide comprising a plurality of antigen binding domains or as a polypeptide comprising at least one antigen binding domains which is subsequently treated to form a multivalent composition.

Another aspect of the present invention provides forms of the subject polypeptide or nucleic acid compositions, formulated in a pharmaceutically acceptable carrier and/or diluent. The present invention specifically contemplates the use of such compositions for preparing a pharmaceutical preparation for the treatment of animals, especially humans.

Such pharmaceutical compositions can be used for the treatment of conditions involving unwanted cell proliferation, particularly the treatment of a disorder involving transformed cells expressing MHC class II antigens. For instance, the formulations can be used for the treatment of a disorder selected from B cell non-Hodgkin lymphoma, B cell lymphoma, B cell acute lymphoid leukemia, Burkitt lymphoma, Hodgkin lymphoma, hairy cell leukemia, acute myeloid leukemia, T cell lymphoma, T cell non-Hodgkin lymphoma, chronic myeloid leukemia, chronic lymphoid leukemia, multiple myeloid leukemia and B cell precursor leukemia.

Such pharmaceutical preparations can be used for the treatment of diseases involving unwanted activation of immune cells, such as in the treatment of a disorder selected from rheumatoid arthritis, juvenile arthritis, multiple sclerosis, Grave's disease, insulin-dependent diabetes, narcolepsy, psoriasis, systemic lupus erythematosus, ankylosing spondylitis, transplant rejection, graft vs. host disease, Hashimoto's disease, myasthenia gravis, pemphigus vulgaris, glomerulonephritis, thyroiditis, pancreatitis, insulitis, primary biliary cirrhosis, irritable bowel disease and Sjogren syndrome.

Another aspect of the present invention provides a diagnostic composition including the polypeptide or nucleic acid compositions of the present invention. In certain embodiments, the diagnostic composition includes a polypeptide composition and a cross-linking moiety or moieties.

5   Still another aspect of the present invention provides a method for killing a cell expressing an antigen on the surface of said cell comprising the step of contacting the cell with a multivalent polypeptide composition of the subject invention.

Another aspect of the invention provides a method to identify patients that can be treated with a multivalent polypeptide composition, formulated in a pharmaceutically

10   acceptable carrier and/or diluent comprising the steps of:

    a. isolating cells from a patient;

    b. contacting said cells with the composition; and

    c. measuring the degree of killing or immunosuppression of said cells.

The present invention also provides a kit to identify patients that can be treated

15   with a multivalent polypeptide composition of the present invention, formulated in a pharmaceutically acceptable carrier and/or diluent comprising:

    a. a multivalent polypeptide composition; and

    b. means to measure the degree of killing or immunosuppression of said cells.

In certain embodiments, the kit includes a multivalent polypeptide composition,

20   and a cross-linking moiety. In other embodiments, the kit includes

    a. a multivalent polypeptide composition,

    b. a detectable moiety or moieties, and

    c. reagents and/or solutions to effect and/or detect binding of (a) to an antigen.

Another aspect of the present invention provides a cytotoxic composition

25   comprising a multivalent polypeptide composition operably linked to a cytotoxic agent.

Stil another aspect of the invention provides an immunogenic composition comprising a multivalent polypeptide composition operablly linked to an immunogenic agent.

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Another aspect of the present invention provides a method to kill a cell comprising contacting the cell with a multivalent polypeptide composition operabled linked a cytotoxic or immunogenic agent.

Another aspect of the invention provides a method for treating a human to reduce the severity of disorder involving unwanted proliferation/activation of cells expressing the human β-chain of HLA-DR, comprising administering to the patient a a multivalent polypeptidepolypeptide of the present invention. In certain embodiments, the disorder involves unwanted proliferation/activation of lymphoid cells, e.g., selected from B cell non-Hodgkin lymphoma, B cell lymphoma, B cell acute lymphoid leukemia, Burkitt lymphoma, Hodgkin lymphoma, hairy cell leukemia, acute myeloid leukemia, T cell lymphoma, T cell non-Hodgkin lymphoma, chronic myeloid leukemia, chronic lymphoid leukemia, multiple myeloid leukemia and B cell precursor leukemia.

Another aspect of the invention provides a use of a multivalent polypeptide composition operably linked a cytotoxic or immunogenic agent for preparing a pharmaceutical preparation for the treatment of animals

According to a preferred embodiment, the polypeptide is directed to a lymphoid cell or a non-lymphoid cell that expresses MHC class II molecules. The latter type of cells occur for example at pathological sites of inflammation and/or autoimmune diseases, e.g. synovial cells, endothelial cells, thyroid stromal cells and glial cells, or it may also comprise genetically altered cells capable of expressing MHC class II molecules.

Preferably, the polypeptide is directed to lymphoid tumor cells. More preferred are lymphoid tumor cells that represent a disease selected from B cell non-Hodgkin lymphoma, B cell lymphoma, B cell acute lymphoid leukemia, Burkitt lymphoma, Hodgkin lymphoma, hairy cell leukemia, acute myeloid leukemia and B cell precursor leukemia. Most preferred are lymphoid tumor cells from a cell line taken from the list of GRANTA-519, PRIESS, KARPAS-422, DOHH-2, MHH-CALL-4, MN-60, BJAB, L-428, BONNA-12, EOL-1, MHH-PREB-1 and MHH-CALL-2 cell lines.

In certain embodiments, the polypeptide binds to at least one epitope in the alpha-chain of an HLA-DR molecule. In such embodiments, the polypeptide preferably binds to at least one epitope in the first domain of the alpha-chain of HLA-DR, the first domain being the N-terminal domain of the chain. For instance, the polypeptide can be selected to

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bind to at least one epitope within the alpha-helix ranging from Glu55 to Tyr79 of the alpha-chain of HLA-DR.

In other embodiments, the polypeptide binds to at least one epitope in the beta-chain of an HLA-DR molecule. Preferably, the polypeptide binds to at least one epitope in the first domain of the beta-chain of HLA-DR, the first domain being the N-terminal domain of the chain.

In certain embodiments, the mechanism of killing a target cell induced by the polypeptide involves an innate pre-programmed process of said cell. Preferably, the polypeptide induces a killing mechanism, which is not an apoptotic cell death process.

In a preferred embodiment the polypeptide induces a killing mechanism which is dependent on the action of proteases other than caspases, e.g., is a caspase-independent mechanism.

In a further embodiment the multivalent composition comprises at least one full antibody which is selected from classes IgG_1, 2a, 2b, 3, 4, IgA, and IgM.

In a further embodiment the multivalent composition comprises at least one of a F(ab')$_2$ antibody fragment or mini-antibody fragment.

In a preferred embodiment the multivalent composition comprises at least two monovalent antibody fragments selected from Fv, scFv, dsFv and Fab fragments, and further comprises a cross-linking moiety or moieties.

The present invention also provides a composition including a polypeptide comprising at least one antibody-based antigen-binding domain with a binding specificity for human HLA-DR wherein binding of said polypeptide to said epitope causes or leads to suppression of the immune response and wherein said antigen-binding domain includes a combination of a VH domain and a VL domain, wherein said combination is found in one of the clones taken from the list of MS-GPC-1, MS-GPC-6, MS-GPC-8, MS-GPC-10, MS-GPC-8-1, MS-GPC-8-6, MS-GPC-8-9, MS-GPC-8-10, MS-GPC-8-17, MS-GPC-8-18, MS-GPC-8-27, MS-GPC-8-6-2, MS-GPC-8-6-19, MS-GPC-8-6-27, MS-GPC-8-6-45, MS-GPC-8-6-13, MS-GPC-8-6-47, MS-GPC-8-10-57, MS-GPC-8-27-7, MS-GPC-8-27-10 and MS-GPC-8-27-41.

Another immunosuppressive composition of the present invention includes a polypeptide comprising at least one antibody-based antigen-binding domain with a binding specificity for a human MHC class II antigen with a K_d of 1 μM, 100 nM, 10 nM or even 1 nM or less, wherein treating cells expressing MHC class II antigen with the polypeptide causes or leads to suppression of the immune response, e.g., preferably with an IC_{50} of 1 μM, 100 nM, 10 nM or even 1 nM or less.

Another immunosuppressive composition of the present invention includes a polypeptide comprising at least one antibody-based antigen-binding domain of human composition with a binding specificity for a human MHC class II antigen with a K_d of 1 μM , 100 nM, 10 nM or even 1 nM or less, the antigen-binding domain being isolated by a method which includes isolation of human VL and VH domains from a recombinant antibody display library by ability to bind to human MHC class II antigen, wherein treating cells that express MHC class II with said polypeptide causes or leads to suppression of the immune response.

The subject immunosuppressive compositions can be generated using the antigen-binding domain isolated by the further steps of:

a. generating a library of mutations at least one of the CDR1, CDR2 and CDR3 domains of one or both of the VL and VH domains, and

b. isolation of VL and VH domains from the library of variants by ability to bind to human MHC class II antigen with a K_d of 1 μM or less.

In preferred embodiments, the antigen binding domains of the immunosuppressive composition binds to HLA-DR, and preferably to the β-chain of HLA-DR, and even more preferably to the first domain of the β-chain of HLA-DR.

In certain preferred embodiments, the immunosuppressive composition have an IC_{50} for suppressing the immune response of 1 μM, 100 nM, 10 nM or even 1 nM or less.

In certain preferred embodiments, the immunosuppressive composition have an IC_{50} for inhibiting of IL-2 secretion of 1 μM, 100 nM, 10 nM or even 1 nM or less.

In certain preferred embodiments, the immunosuppressive composition have an IC_{50} for inhibiting of T cell proliferation of 1 μM, 100 nM, 10 nM or even 1 nM or less.

In certain preferred embodiments, the immunosuppressive composition have antigen-binding domain that bind to an epitope of one or more HLA-DR types selected from the group consisting of DR1-0101, DR2-15021, DR3-0301, DR4Dw4-0401, DR4Dw10-0402, DR4Dw14-0404, DR6-1302, DR6-1401, DR8-8031, DR9-9012, DRw53-B4*0101 and DRw52-B3*0101, and in preferred embodiments, the antigen-binding domain binds to at least 5 different of said HLA-DR types (e.g., are pan-DR).

In certain embodiments, the immunosuppressive composition have antigen-binding domain includes a combination of a VH domain and a VL domain, wherein said combination is found in one of the clones taken from the list of MS-GPC-1, MS-GPC-6, MS-GPC-8, MS-GPC-10, MS-GPC-8-1, MS-GPC-8-6, MS-GPC-8-9, MS-GPC-8-10, MS-GPC-8-17, MS-GPC-8-18, MS-GPC-8-27, MS-GPC-8-6-2, MS-GPC-8-6-19, MS-GPC-8-6-27, MS-GPC-8-6-45, MS-GPC-8-6-13, MS-GPC-8-6-47, MS-GPC-8-10-57, MS-GPC-8-27-7, MS-GPC-8-27-10 and MS-GPC-8-27-41.

In certain embodiments, the immunosuppressive composition have antigen-binding domain includes a combination of HuCAL VH2 and HuCAL Vλ1, wherein the VH CDR3 sequence is taken from the consensus CDR3 sequence:

XXXXRGXFDX (SEQ ID No. 1)

wherein each X independently represents any amino acid residue; and,

wherein the VL CDR3 sequence is taken from the consensus CDR3 sequence:

QSYDXXXX (SEQ ID No. 2)

wherein each n independently represents any amino acid residue.

For instance, the VH CDR3 sequence is SPRYGAFDY (SEQ ID No. 3) and/or the VL CDR3 sequence is QSYDLIRH (SEQ ID No. 4) or QSYDMNVH (SEQ ID No. 5).

In certain embodiments, the immunosuppressive composition the antigen-binding domain competes with antigen binding by an antibody having a VH CDR3 sequence represented by the general formula:

XXXXRGXFDX (SEQ ID No. 1)

wherein each X independently represents any amino acid residue; and,

a VL CDR3 sequence represented by the general formula:

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QSYDXXXX (SEQ ID No. 2)

wherein each X independently represents any amino acid residue.

In certain embodiments, the immunosuppressive composition the antigen-binding domain includes a VL CDR1 sequence represented in the general formula:

5   SGSXXNIGXNYVX (SEQ ID No. 6)

wherein each n independently represents any amino acid residue. For example, the CDR1 sequence is SGSESNIGNNYVQ (SEQ ID No. 7).

In certain embodiments, the subject immunosuppressive compositions suppress the immune response by one or more of (a) down-regulation of expression of the antigen to
10   which the polypeptide binds; or (b) inhibiting of the interaction between said cell and other cells, wherein said interaction would normally lead to an immune response.

Another aspect of the present invention provides nucleic acids which including a coding sequence for an immunosuppressive polypeptide of the present invention. In certain embodiments, the nucleic acid can be provided as part of a vector, e.g., including the
15   coding sequence and a transcriptional regulatory sequence operably linked thereto. The nucleic acid and vectors of the present invention can be provided as part of a host cell, e.g., which can be used to to produce an immunosuppressive composition.

Another aspect of the present invention provides a method for suppressing activation and/or proliferation of a lymphocyte, comprising contacting the cell with an
20   immunosuppressive polypeptide of the present invention.

The present invention also provides a pharmaceutical preparation comprising the a polypeptide including an antibody-based antigen-binding domain with a binding specificity for a human MHC class II antigen with a K_d of 1 µM or less, e.g., in an amount sufficient to suppress an immune response in an animal, inhibit IL-2 secretion in an
25   animal, and/or inhibit T cell proliferation in an animal.

Another aspect of the present invention relates to the use of a polypeptide including an antibody-based antigen-binding domain with a binding specificity for a human MHC class II antigen with a K_d of 1 µM or less, for the preparation of a pharmaceutical composition for the treatment of animals, such as where said animals are human.

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The subject immunosuppressive pharmaceutical preparations can be used for suppressing IL-2 secretion by a cell of the immune system. For example, these preparations can be administered to the patient in an effective amount to reduce the level of immunological responsiveness in the patient.

5   Still another aspect of the present invention provides a method for suppressing IL-2 secretion by a lymphocyte, comprising contacting the cell with an immunosuppressive polypeptide of the present invention.

The subject method can be used for immunosuppressing a human, e.g., by administering to the patient an effective amount of an immunosuppressive polypeptide of 10   the present invention to reduce the level of immunological responsiveness.

The invention further relates to a diagnostic composition containing at least one polypeptide and/or nucleic acid according to the invention, optionally together with further reagents, such as buffers, for performing the diagnosis.

In a preferred embodiment the diagnostic composition contains the polypeptide 15   according to the invention cross-linked by at least one moiety. Such moieties can be for example antibodies recognizing an epitope present on the polypeptide such as the FLAG peptide epitope (Hopp et al., 1988; Knappik and Plückthun, 1994) or bifunctional chemical compounds reacting with a nucleophilic amino acid side chain as present in cysteine or lysine (King et al., 1994). Methods for cross-linking polypeptides are well 20   known to the practitioner of ordinary skill in the art.

A diagnostic composition containing at least one nucleic acid and/or variant thereof according to the invention is also contemplated.

Furthermore, the present invention relates to a kit comprising at least one polypeptide according to the present invention, and a cross-linking moiety.

25   Additionally, the present invention relates to a kit comprising (i) a polypeptide according to the present invention, (ii) a detectable moiety or moieties, and (iii) reagents and/or solutions to effect and/or detect binding of (i) to an antigen.

The present invention further relates to a multivalent composition comprising at least one polypeptide and comprising at least two antigen binding domains.

Still another aspect of the present invention provides a method for conducting a pharmaceutical business comprising:

    a. isolating one or more antigen-binding domains that bind to antigens expressed on the surface of human cells;

    b. generating a multivalent composition comprising a plurality of said antigen-binding domains, which multivalent composition kills with an EC_{50} of 50 nM or less transformed or activated cells where neither cytotoxic entities nor immunological mechanisms are needed to cause or lead to said killing.;

    c. conducting therapeutic profiling of the multivalent compositions for efficacy and toxicity in animals;

    d. preparing a package insert describing the multivalent composition for treatment of proliferative disorders; and

    e. marketing the multivalent composition for treatment of proliferative disorders.

The present invention also provides a method for conducting a life science business comprising:

    a. isolating one or more antigen-binding domains that bind to antigens expressed on the surface of human cells;

    b. generating a multivalent composition comprising a plurality of said antigen-binding domains, which multivalent composition kills with an EC_{50} of 50 nM or less transformed or activated cells where neither cytotoxic entities nor immunological mechanisms are needed to cause or lead to said killing.;

    c. licensing, jointly developing or selling, to a third party, the rights for selling the multivalent compositions.

In such embodiments, the the antigen-binding domain can be isolated by a method which includes

    a. isolation of VL and VH domains of human composition from a recombinant antibody display library by ability to bind to epitopes of HLA-DR,

b. generating a library of variants at least one of the CDR1, CDR2 and CDR3 domains of one or both of the VL and VH domains, and

c. isolation of VL and VH domains from the library of variants by ability to epitopes of HLA-DR with a Kd of 1 µM or less.

5   Another business method contemplated by the present invention includes:

a. isolating one or more antigen-binding domains that bind to MHC class II expressed on the surface of human cells with a K_d of 1 µM or less;

b. generating a composition comprising said antigen-binding domains, which composition is immunosuppressant with an IC_{50} of 100 nM or less;

10   c. conducting therapeutic profiling of the multivalent compositions for efficacy and toxicity in animals;

d. preparing a package insert describing the use of the composition for immunosuppression therapy; and

e. marketing the multivalent composition for use as an immunosuppressant.

15   The present invention also provides a method for conducting a life science business comprising:

a. isolating one or more antigen-binding domains that bind to MHC class II expressed on the surface of human cells with a K_d of 1 µM or less;

b. generating a composition comprising said antigen-binding domains, which
20   composition is immunosuppressant with an IC_{50} of 100 nM or less;

c. licensing, jointly developing or selling, to a third party, the rights for selling the compositions.

As used herein, the term "peptide" relates to molecules consisting of one or more chains of multiple, i. e. two or more, amino acids linked via peptide bonds.

25   The term "protein" refers to peptides where at least part of the peptide has or is able to acquire a defined three-dimensional arrangement by forming secondary, tertiary, or quaternary structures within and/or between its peptide chain(s). This definition comprises proteins such as naturally occurring or at least partially artificial proteins, as well as

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fragments or domains of whole proteins, as long as these fragments or domains are able to acquire a defined three-dimensional arrangement as described above.

The term "polypeptide" is used interchangeably to refer to peptides and/or proteins. Moreover, the terms "polypeptide " and "protein", as the context will admit, include multi-

5   chain protein complexes, such as immunoglobulin polypeptides having separate heavy and light chains.

In this context, "polypeptide comprising at least one antibody-based antigen-binding domain" refers to an immunoglobulin (or antibody) or to a fragment thereof. The term "fragment", with respect to antibody domains and the like, refers to a fragment of an

10   immunoglobulin which retains the antigen-binding moiety of an immunoglobulin. Functional immunoglobulin fragments according to the present invention may be Fv (Skerra and Plückthun, 1988), scFv (Bird et al., 1988; Huston et al., 1988), disulfide-linked Fv (Glockshuber et al., 1992; Brinkmann et al., 1993), Fab, F(ab')2 fragments or other fragments well-known to the practitioner skilled in the art, which comprise the

15   variable domains of an immunoglobulin or functional immunoglobulin fragment.

Examples of polypeptides consisting of one chain are single-chain Fv antibody fragments, and examples for polypeptides consisting of multiple chains are Fab antibody fragments.

The term "antibody" as used herein, unless indicated otherwise, is used broadly to

20   refer to both antibody molecules and a variety of antibody derived molecules. Such antibody derived molecules comprise at least one variable region (either a heavy chain of light chain variable region) and include such fragments as described above, as well as individual antibody light chains, individual antibody heavy chains, chimeric fusions between antibody chains and other molecules, and the like.

25   The "antigen-binding site" of an immunoglobulin molecule refers to that portion of the molecule that is necessary for binding specifically to an antigen. An antigen binding site preferably binds to an antigen with a K_d of 1 μM or less, and more preferably less than 100 nM, 10 nM or even 1 nM in certain instances. Binding specifically to an antigen is intended to include binding to the antigen which significantly higher affinity than binding

30   to any other antigen.

The antigen binding site is formed by amino acid residues of the N-terminal variable ("V") regions of the heavy ("H") and light ("L") chains. Three highly divergent stretches within the V regions of the heavy and light chains are referred to as "hypervariable regions" which are interposed between more conserved flanking stretches known as "framework regions," or "FRs". Thus the term "FR" refers to amino acid sequences which are naturally found between and adjacent to hypervariable regions in immunoglobulins. In an antibody molecule, the three hypervariable regions of a light chain and the three hypervariable regions of a heavy chain are disposed relative to each other in three dimensional space to form an antigen-binding surface. The antigen-binding surface is complementary to the three-dimensional surface of a bound antigen, and the three hypervariable regions of each of the heavy and light chains are referred to as "complementarity-determining regions," or "CDRs."

For the purposes of this application, "valent" refers to the number of antigen binding sites the subject polypeptide possess. Thus, a bivalent polypeptide refers to a polypeptide with two binding sites. The term "multivalent polypeptide" encompasses bivalent, trivalent, tetravalent, etc. forms of the polypeptide.

As used herein, a "multivalent composition" means a composition comprising a polypeptide having at least two of said antigen-binding domains, e.g.,a multivalent polypeptide. Preferably, said at least two antigen-binding domains are in close proximity so as to mimic the structural arrangement relative to each other of binding sites comprised in a full immunoglobulin molecule. Examples for multivalent compositions are full immunoglobulin molecules (e.g. IgG, IgA or IgM molecules) or multivalent fragments thereof (e.g. F(ab')$_2$). Additionally, multivalent compositions of higher valencies may be formed from two or more multivalent compositions (e.g. two or more full immunoglobulin molecules), e.g. by cross-linking. Multivalent compositions, however, may be formed as well from two or more monovalent immunoglobulin fragments, e.g. by self-association as in mini-antibodies, or by cross-linking.

Accordingly, an "antibody-based antigen-binding domain" refers to polypeptide or polypeptides which form an antigen-binding site retaining at least some of the structural features of an antibody, such as at least one CDR sequence. In certain preferred embodiments, antibody-based antigen-binding domain includes sufficient structure to be

considered a variable domain, such as three CDR regions and interspersed framework regions. Antibody-based antigen-binding domain can be formed single polypeptide chains corresponding to VH or VL sequences, or by intermolecular or intramolecular association of VH and VL sequences.

5   The term "recombinant antibody library" describes a variegated library of antigen binding domains. For instance, the term includes a collection of display packages, e.g., biological particles, which each have (a) genetic information for expressing at least one antigen binding domain on the surface of the particle, and (b) genetic information for providing the particle with the ability to replicate. For instance, the package can display a

10   fusion protein including an antigen binding domain. The antigen binding domain portion of the fusion protein is presented by the display package in a context which permits the antigen binding domain to bind to a target epitope that is contacted with the display package. The display package will generally be derived from a system that allows the sampling of very large variegated antibody libraries. The display package can be, for

15   example, derived from vegetative bacterial cells, bacterial spores, and bacterial viruses.

In an exemplary embodiment of the present invention, the display package is a phage particle which comprises a peptide fusion coat protein that includes the amino acid sequence of a test antigen binding domains. Thus, a library of replicable phage vectors, especially phagemids (as defined herein), encoding a library of peptide fusion coat proteins

20   is generated and used to transform suitable host cells. Phage particles formed from the chimeric protein can be separated by affinity selection based on the ability of the antigen binding site associated with a particular phage particle to specifically bind a target eptipope. In a preferred embodiment, each individual phage particle of the library includes a copy of the corresponding phagemid encoding the peptide fusion coat protein displayed

25   on the surface of that package. Exemplary phage for generating the present variegated peptide libraries include M13, f1, fd, If1, Ike, Xf, Pf1, Pf3, λ, T4, T7, P2, P4, φX-174, MS2 and f2.

The term "generating a library of variants of at least one of the CDR1, CDR2 and CDR3" refers to a process of generating a library of variant antigen binding sites in which

30   the members of the library differ by one or more changes in CDR sequences, e.g., not FR

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sequences. Such libraries can be generated by random or semi-random mutagenesis of one or more CDR sequences from a selected antigen binding site.

As used herein, an "antibody-based antigen-binding domain of human composition" preferably means a polypeptide comprising at least an antibody VH domain and an antibody VL domain, wherein a homology search in a database of protein sequences comprising immunoglobulin sequences results for both the VH and the VL domain in an immunoglobulin domain of human origin as hit with the highest degree of sequence identity. Such a homology search may be a BLAST search, e.g. by accessing sequence databases available through the National Center for Biological Information and performing a "BasicBLAST" search using the "blastp" routine. See also Altschul et al. (1990) J Mol Biol 215:403-410. Preferably, such a composition does not result in an adverse immune response thereto when administered to a human recipient. In certain preferred embodiments, the subject antigen-binding domains of human composition include the framework regions of native human immunoglobulins, as may be cloned from activated human B cells, though not necessarily all of the CDRs of a native human antibody.

As used herein, the term "mini-antibody fragment" means a multivalent antibody fragment comprising at least two antigen-binding domains multimerized by self-associating domains fused to each of said domains (Pack, 1994), e.g. dimers comprising two scFv fragments, each fused to a self-associating dimerization domain. Dimerization domains, which are particularly preferred, include those derived from a leucine zipper (Pack and Plückthun, 1992) or helix-turn-helix motif (Pack et al., 1993).

As used herein, "activated cells" means cells of a certain population of interest, which are not resting. Activation might be caused by mitogens (e.g., lipopoysaccharide, phytohemagglutinine) or cytokines (e.g., interferon gamma). Preferably, said activation occurs during tumor transformation (e.g., by Epstein-Barr virus, or "spontaneously"). Preferably, activated cells are characterized by the features of MHC class II molecules expressed on the cell surface and one or more additional features including increased cell size, cell division, DNA replication, expression of CD45 or CD11 and production/secretion of immunoglobulin.

As used herein, "non-activated cells" means cells of a population of interest, which are resting and non-dividing. Said non-activated cells may include resting B cells as purified from healthy human blood. Such cells can, preferably, be characterized by lack or reduced level of MHC class II molecules expressed on the cell surface and lack or reduced level of one or more additional features including increased cell size, cell division, DNA replication, expression of CD45 or CD11 and production/secretion of immunoglobulin.

As used herein, the term "EC_{50}" means the concentration of multivalent forms of the subject compositions which produces 50% of its maximum response or effect, such as cell killing.

"At least 5-fold lower EC_{50}" means that the concentration of a multivalent composition comprising at least one polypeptide of the present invention that is required to kill 50% of activated cells is at least five times less than the concentration of the multivalent composition required to kill non-activated cells. Preferably, the concentration required to kill 50% of non-activated cells cannot be achieved with therapeutically appropriate concentrations of the multivalent composition. Most preferably, the EC_{50} value is determined in the test described below in the appended examples.

The term "immunosuppress" refers to the prevention or diminution of the immune response, as by irradiation or by administration of antimetabolites, antilymphocyte serum, or specific antibody.

The term "immune response" refers to any response of the immune system, or a cell forming part of the immune system (lymphocytes, granulocytes, macrophages, etc), to an antigenic stimulus, including, without limitation, antibody production, cell-mediated immunity, and immunological tolerance.

As used herein, the term "IC_{50}" with respect to immunosuppression, refers to the concentration of the subject compositions which produces 50% of its maximum response or effect, such as inhibition of an immune response, such as may be manifest by inhibition of IL2 secretion, down-regulation of IL2 expression, or reduced rate of cell proliferation.

The phrase "cytotoxic entities", with reference to a manner of cell killing, refers to mechanisms which are complement-dependent. Likewise, the phrase "immuological

mechanism" , with reference to a manner of cell killing, refers to macrophage-dependent and/or neutrophil-dependent killing of cells.

"Lymphoid cells" when used in reference to a cell line or a cell, means that the cell line or cell is derived from the lymphoid lineage. "Lymphoid cells" include cells of the B and the T lymphocyte lineages, and of the macrophage lineage.

Cells, which are "non lymphoid cells and express MHC class II", are cells other than lymphoid cells that express MHC class II molecules, e.g. during a pathological inflammatory response. For example, said cells may include synovial cells, endothelial cells, thyroid stromal cells and glial cells, and it may also comprise genetically altered cells capable of expressing MHC class II molecules.

The terms "apoptosis" and "apoptotic activity" refer to the form of cell death in mammals that is accompanied by one or more characteristic morphological and biochemical features, including nuclear and condensation of cytoplasm, chromatin aggregation, loss of plasma membrane microvilli, partition of cytoplasm and nucleus into membrane bound vesicles (apoptotic bodies) which contain ribosomes, morphologically intact mitochondria and nuclear material, degradation of chromosomal DNA or loss of mitochondrial function. Apoptosis follows a very stringent time course and is executed by caspases, a specific group of proteases. Apoptotic activity can be determined and measured, for instance, by cell viability assays, Annexin V staining or caspase inhibition assays. Apoptosis can be induced using a cross-linking antibody such as anti-CD95 as described in Example H.

As used herein, the term "first domain of the α-chain of HLA-DR" means the N-terminal domain of the alpha-chain of the MHC class II DR molecule.

As used herein, the term "first domain of the β-chain of HLA-DR" means the N-terminal domain of the beta-chain of the MHC class II DR molecule.

The term "innate pre-programmed process" refers to a process that, once it is started, follows an autonomous cascade of mechanisms within a cell, which does not require any further auxillary support from the environment of said cell in order to complete the process.

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As used herein, the term "HuCAL" refers to a fully synthetic human combinatorial antibody library as described in Knappik et al. (2000).

The term "variable region" as used herein in reference to immunoglobulin molecules has the ordinary meaning given to the term by the person of ordinary skill in the act of immunology. Both antibody heavy chains and antibody light chains may be divided into a "variable region" and a "constant region". The point of division between a variable region and a heavy region may readily be determined by the person of ordinary skill in the art by reference to standard texts describing antibody structure, e.g., Kabat et al "Sequences of Proteins of Immunological Interest: 5th Edition" U.S. Department of Health and Human Services, U.S. Government Printing Office (1991).

As used herein, the term "CDR3" refers to the third complementarity-determining region of the VH and VL domains of antibodies or fragments thereof, wherein the VH CDR3 covers positions 95 to 102 (possible insertions after positions 100 listed as 100a to 100z), and VL CDR3 positions 89 to 96 (possible insertions in Vλ after position 95 listed as 95a to 95c) (see Knappik et al., 2000).

As used herein, the term "hybridizes under stringent conditions" is intended to describe conditions for hybridization and washing under which nucleotide sequences at least 60% homologous to each other typically remain hybridized to each other. Preferably, the conditions are such that sequences at least 65%, more preferably at least 70%, and even more preferably at least 75% homologous to each other typically remain hybridized to each other. Such stringent conditions are known to those skilled in the art and can be found in Current Protocols in Molecular Biology, John Wiley & Sons, New York. (1989), 6.3.1-6.3.6. A preferred, non-limiting example of stringent hybridization conditions is hybridization in 6 x sodium chloride/sodium citrate (SSC) at about 45°C, followed by one or more washes in 0.2 x SSC, 0.1% SDS at 50° - 65°C.

The term "immunosuppression" as used herein refers to suppression of immune response resulting from T-cell activation, particularly antigen-mediated T-cell activation. T-cell activation by antigen can be measured by a variety of art-recognized methods. For example, IL-2 secretion by activated T-cells can be used to measure antigen-stimulated T-cell activation. Alternatively, T-cell proliferation as measured by a number of art-recognized methods (such as ^{3}H-labeled dNTP incorporation into replicating DNA) can be

used to monitor antigen-induced T-cell activation. Immunesuppression of T-cell activation by mAb's or fragments thereof refers to suppression of immune response as measured by any one of the proper methods (such as the ones mentioned above) by at least about 50%, or 60%, more preferably at least about 70% or 80%, most preferably at least about 85% or

5   even 90%, 95%, 99%.

A "protein coding sequence" or a sequence which "encodes" a particular polypeptide or peptide, is a nucleic acid sequence which is transcribed (in the case of DNA) and translated (in the case of mRNA) into a polypeptide in vitro or in vivo when placed under the control of appropriate regulatory sequences. The boundaries of the coding

10   sequence are determined by a start codon at the 5' (amino) terminus and a translation stop codon at the 3' (carboxy) terminus. A coding sequence can include, but is not limited to, cDNA from procaryotic or eukaryotic mRNA, genomic DNA sequences from procaryotic or eukaryotic DNA, and even synthetic DNA sequences. A transcription termination sequence will usually be located 3' to the coding sequence.

15   Likewise, "encodes", unless evident from its context, will be meant to include DNA sequences which encode a polypeptide, as the term is typically used, as well as DNA sequences which are transcribed into inhibitory antisense molecules.

As used herein, the term "transfection" means the introduction of a heterologous nucleic acid, e.g., an expression vector, into a recipient cell by nucleic acid-mediated gene

20   transfer. "Transient transfection" refers to cases where exogenous DNA does not integrate into the genome of a transfected cell, e.g., where episomal DNA is transcribed into mRNA and translated into protein. A cell has been "stably transfected" with a nucleic acid construct when the nucleic acid construct is capable of being inherited by daughter cells.

"Expression vector" refers to a replicable DNA construct used to express DNA

25   which encodes the desired protein and which includes a transcriptional unit comprising an assembly of (1) agent(s) having a regulatory role in gene expression, for example, promoters, operators, or enhancers, operatively linked to (2) a DNA sequence encoding a desired protein (such as a polypeptide of the present invention) which is transcribed into mRNA and translated into protein, and (3) appropriate transcription and translation

30   initiation and termination sequences. The choice of promoter and other regulatory elements generally varies according to the intended host cell. In general, expression

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vectors of utility in recombinant DNA techniques are often in the form of "plasmids" which refer to circular double stranded DNA loops which, in their vector form are not bound to the chromosome. In the present specification, "plasmid" and "vector" are used interchangeably as the plasmid is the most commonly used form of vector. However, the invention is intended to include such other forms of expression vectors which serve equivalent functions and which become known in the art subsequently hereto.

In the expression vectors, regulatory elements controlling transcription or translation can be generally derived from mammalian, microbial, viral or insect genes The ability to replicate in a host, usually conferred by an origin of replication, and a selection gene to facilitate recognition of transformants may additionally be incorporated. Vectors derived from viruses, such as retroviruses, adenoviruses, and the like, may be employed.

"Transcriptional regulatory sequence" is a generic term used throughout the specification to refer to DNA sequences, such as initiation signals, enhancers, and promoters and the like which induce or control transcription of protein coding sequences with which they are operably linked. It will be understood that a recombinant gene can be under the control of transcriptional regulatory sequences which are the same or which are different from those sequences which control transcription of the naturally-occurring form of the gene, if any.

"Operably linked" when describing the relationship between two DNA regions simply means that they are functionally related to each other. For example, a promoter or other transcriptional regulatory sequence is operably linked to a coding sequence if it controls the transcription of the coding sequence.

As used herein, the term "fusion protein" is art recognized and refer to a chimeric protein which is at least initially expressed as single chain protein comprised of amino acid sequences derived from two or more different proteins, e.g., the fusion protein is a gene product of a fusion gene.

As used herein, "proliferating" and "proliferation" refer to cells undergoing mitosis.

The "growth rate" of a cell refers to the rate of proliferation of the cell and the state of differentiation of the cell.

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The term "cell-proliferative disorder" denotes malignant as well as nonmalignant populations of transformed cells which morphologically often appear to differ from the surrounding tissue.

As used herein, "transformed cells" refers to cells which have spontaneously 5 converted to a state of unrestrained growth, i.e., they have acquired the ability to grow through an indefinite number of divisions in culture. Transformed cells may be characterized by such terms as neoplastic, anaplastic and/or hyperplastic, with respect to their loss of growth control.

As used herein, "immortalized cells" refers to cells which have been altered via 10 chemical and/or recombinant means such that the cells have the ability to grow through an indefinite number of divisions in culture.

As used herein the term "animal" refers to mammals, preferably mammals such as humans. Likewise, a "patient" or "subject" to be treated by the method of the invention can mean either a human or non-human animal.

15 According to the methods of the invention, the peptide may be administered in a pharmaceutically acceptable composition. In general, pharmaceutically-acceptable carriers for monoclonal antibodies, antibody fragments, and peptides are well-known to those of ordinary skill in the art. As used herein, the term "pharmaceutically acceptable carrier" includes any and all solvents, dispersion media, coatings, antibacterial and antifungal 20 agents, isotonic and absorption delaying agents and the like. In preferred embodiments, the subject carrier medium which does not interfere with the effectiveness of the biological activity of the active ingredients and which is not excessively toxic to the hosts of the concentrations of which it is administered. The administration(s) may take place by any suitable technique, including subcutaneous and parenteral administration, preferably 25 parenteral. Examples of parenteral administration include intravenous, intraarterial, intramuscular, and intraperitoneal, with intravenous being preferred.

The pharmaceutical forms suitable for injectable use include sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersions. In all cases the form must be sterile and must be fluid 30 to the extent that easy syringability exists. It must be stable under the conditions of manufacture and storage and must be preserved against the contaminating action of

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microorganisms, such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol, and liquid polyethylene glycol, and the like), suitable mixtures thereof, and vegetable oils. The proper fluidity can be maintained, for example, by the use of a coating, such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. The prevention of the action of microorganisms can be brought about by various antibacterial an antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the use in the compositions of agents delaying absorption, for example, aluminum monostearate and gelatin.

Sterile injectable solutions are prepared by incorporating the active compounds, e.g., the subject polypeptides, in the required amount in the appropriate solvent with various of the other ingredients enumerated above, as required, followed by filtered sterilization. Generally, dispersions are prepared by incorporating the various sterilized active ingredients into a sterile vehicle which contains the basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum-drying and freeze-drying techniques which yield a powder of the active ingredient plus any additional desired ingredient from a previously sterile-filtered solution thereof.

For oral administration the polypeptides of the present invention may be incorporated with excipients and used in the form of non-ingestible mouthwashes and dentifrices. A mouthwash may be prepared incorporating the active ingredient in the required amount in an appropriate solvent, such as a sodium borate solution (Dobell's Solution). The active ingredient may also be dispersed in dentifrices, including: gels, pastes, powders and slurries. The active ingredient may be added in a therapeutically effective amount to a paste dentifrice that may include water, binders, abrasives, flavoring agents, foaming agents, and humectants.

The compositions of the present invention may be formulated in a neutral or salt form. Pharmaceutically-acceptable salts include the acid addition salts (formed with the

free amino groups of the protein) and which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or such organic acids as acetic, oxalic, tartaric, mandelic, and the like. Salts formed with the free carboxyl groups can also be derived from inorganic bases such as, for example, sodium, potassium, ammonium, calcium, or

5   ferric hydroxides, and such organic bases as isopropylamine, trimethylamine, histidine, procaine and the like.

For parenteral administration in an aqueous solution, for example, the solution should be suitably buffered if necessary and the liquid diluent first rendered isotonic with sufficient saline or glucose. These particular aqueous solutions are especially suitable for

10   intravenous, intramuscular, subcutaneous and intraperitoneal administration. In this connection, sterile aqueous media which can be employed will be known to those of skill in the art in light of the present disclosure. For example, one dosage could be dissolved in 1 ml of isotonic NaCl solution and either added to 1000 ml of hypodermoclysis fluid or injected at the proposed site of infusion, (see for example, "Remington's Pharmaceutical

15   Sciences" 15th Edition, pages 1035-1038 and 1570-1580). Some variation in dosage will necessarily occur depending on the condition of the subject being treated. The person responsible for administration will, in any event, determine the appropriate dose for the individual subject. Moreover, for human administration, preparations should meet sterility, pyrogenicity, general safety and purity standards as required by FDA Office of Biologics

20   standards.

Upon formulation, solutions can be administered in a manner compatible with the dosage formulation and in such amount as is therapeutically effective. The formulations are easily administered in a variety of dosage forms such as injectable solutions, drug release capsules and the like.

25   As used herein, the term "prophylactic or therapeutic" treatment refers to administration to the host of the medical condition. If it is administered prior to exposure to the condition, the treatment is prophylactic (i.e., it protects the host against tumor formation), whereas if administered after initiation of the disease, the treatment is therapeutic (i.e., it combats the existing tumor).

30   A multivalent composition of at least one polypeptide according to the invention is capable of causing cell death of activated cells, preferably lymphoid tumor cells without

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requiring any further additional measures such as chemotherapy and with limited immunogenic side effects on the treated patient. Further, the multivalent composition comprising a polypeptide according to the invention has the capability of binding to at least one epitope on the target antigen, however, several epitope binding sites might be

5   combined in one molecule. Preferably, the multivalent composition comprising a polypeptide according to the invention shows at least 5-fold, or more preferably 10-fold higher killing activity against activated cells compared to non-activated cells. This higher activity on activated cells can be expressed as the at least 5-fold lower EC_{50} value on activated versus non-activated cells or as the higher percentage of killing of activated cells

10   versus non-activated cells when using the same concentration of protein. Under the latter alternative, the multivalent composition comprising a polypeptide according to the invention at a given polypeptide concentration kills at least 50%, preferably at least 80%, of activated cells, whereas the same concentration of a multivalent composition comprising a polypeptide according to the invention under the same incubation conditions

15   kills less than 15%, preferably less than 10% of the non-activated cells. The assay conditions for determining the EC_{50} value and the percentage killing activity are described below.

Brief Description of the Drawings

Figure 1   a) Specificity of the anti-HLA-DR antibody fragments: Binding of MS-GPC-
20   8-27-7, MS-GPC-8-27-10, MS-GPC-8-6-13, MS-GPC-8-27-41, MS-GPC-8-
             6-47, MS-GPC-8-10-57, MS-GPC-8-6-27, MS-GPC-8 and MS-GPC-8-6 to
             HLA-DR protein, negative control proteins (BSA, testosterone-BSA,
             lysozyme and human apotransferrin), and an empty microtiter plate well
             (plastic). Specificity was assessed using standard ELISA procedures. b)
25   Specificity of the anti-HLA-DR antibody fragments MS-GPC-1, 6, 8 & 10
             isolated from the HuCAL library to HLA-DR protein, a mouse-human
             chimeric HLA protein and negative control proteins (lysozyme, transferrin,
             BSA and human β-globulin). Specificity was assessed using standard ELISA
             procedures. A non-related antibody fragment (irr. scFv) was used as control.
30   c) Specificity of anto-HLA-DR antibody fragments (scFv) and some of the

correponding mAb's in IgG format against a panel of human or mousr HLA-DR antigens and unrelated control antigens.

Figure 2   Reactivity of the anti-HLA-DR antibody fragments (MS-GPC-1, 6, 8 and 10, etc.) and IgG forms of MS-GPC-8, MS-GPC-8-10-57, MS-GPC-8-27-41 & MS-GPC-8-6-17 to various cell lines expressing MHC class II molecules. "+" represents strong reactivity as detected using standard immunofluorescence procedure. "+/-" represents weak reactivity and "-" represents no detected reactivity between an anti-HLA-DR antibody fragment or IgG and a particular cell line. Percentage of cells killed by each anti-HLA-DR antibody fragments (scFv) and some of the correponding mAb's in IgG format are also presented. Values greater than 50% are in bold.

Figure 3   Viability of tumor cells in the presence of monovalent and cross-linked anti-HLA-DR antibody fragments as assessed by trypan blue staining. Viability of GRANTA-519 cells was assessed after 4 h incubation with anti-HLA-DR antibody fragments (MS-GPC-1, 6, 8 and 10) with and without anti-FLAG M2 mAb as cross-linking agent.

Figure 4   Scatter plots and fitted logistic curves of data from Table 5 showing improved killing efficiency of 50 nM solutions of the IgG form of the human antibody fragments of the invention treated compared to treatment with 200 nM solutions of murine antibodies. Open circles represent data for cell lines treated with the murine antibodies L243 and 8D1 and closed circles for human antibodies MS-GPC-8, MS-GPC-8-27-41, MS-GPC-8-10-57 and MS-GPC-8-6-13. Fitted logistic curves for human (solid) and mouse (dashed) mAb cell killing data show the overall superiority of the treatment with human mAbs at 50 nM compared to the mouse mAbs despite treatment at a final concentration of 200 nM.

Figure 5   Killing of activated versus non-activated cells. The lymphoma line MHH-PREB-1 cells are activated with Lipopolysaccharide, Interferon-gamma and phyto-hemagglutin, and subsequently incubated for 4 hr with 0.07 to 3300 nM of the IgG forms of the anti-HLA-DR antibody fragments MS-GPC-8-

10-57 and MS-GPC-8-27-41. No loss of viability in the control non-activated MHH-PREB-1 cells is seen. Viable cell recovery is expressed as % of untreated controls.

Figure 6   a) Killing efficiency of control (no antibody, unreactive murine IgG; light grey), and human (MS-GPC-8, MS-GPC-8-10-57 & MS-GPC-8-27-41; dark grey) IgG forms of anti-HLA-DR antibody fragments against CLL cells isolated from patients. Left panel, box-plot display of viability data from 10 patient resting cell cultures against antibodies after incubation for four (h4) and twenty four hours (h24). Right panel box-plot display of viability data from 6 patient activated cell cultures against antibodies after incubation for four (h4) and twenty four hours (h24). b & c) Killing efficiency of human (B8, 1C7277 & 1D09C3) and control murine (L243 & 10F12) anti-DR mAbs against CLL cells isolated from patients. Average % viable cell recovery determined by fluorescence microscopy ± S.D. of CLL cells from 10 patients is shown after 4h or 24h incubation with 100 nM of mAbs, compared to unteated cells. All cell samples showed strong DR expression (mean fluorescence intensity 123-865 by FACS analysis using FITC-L243). In 6c, data from activated vs. resting cells are compared.

Figure 7   Concentration dependent cell viability for certain anti-HLA-DR antibody fragments of the invention. Vertical lines indicate the EC_{50} value estimated by logistic non-linear regression on replica data obtained for each of the antibody fragments. a) Killing curves of cross-linked bivalent anti-HLA-DR antibody F(ab) fragment dimers MS-GPC-10 (circles and solid line), MS-GPC-8 (triangles and dashed line) and MS-GPC-1 (crosses and dotted line). b) Killing curves of cross-linked bivalent anti-HLA-DR antibody (Fab) fragment dimers MS-GPC-8-17 (circles and solid line), and murine IgGs 8D1 (triangles and dashed line) and L243 (crosses and dotted line). c) Killing curves of cross-linked bivalent anti-HLA-DR antibody (Fab) fragment dimers GPC-8-6-2 (crostriangles and dashed line), and murine IgGs 8D1 (circles and solid line) and L243 (crosses and dotted line). d) Killing curves of IgG forms of human anti-HLA-DR antibody fragments

MS-GPC-8-10-57 (crosses and dotted line), MS-GPC-8-27-41 (exes and dash-dot line), and murine IgGs 8D1 (circles and solid line) and L243 (triangles and dashed line). All concentrations are given in nM of the bivalent agent (IgG or cross-linked (Fab) dimer).

5   Figure 8   Mechanism and selectivity of anti-DR induced cell death. a) Comparison of death induced in PRIESS cells by the Fab fragment of human anti-DR mAb B8 crosslinked with anti-FLAG, and anti-CD95 mAb, respectively. Incubation of PRIESS cells with the anti-HLA-DR antibody fragment MS-GPC-8, cross-linked using the anti-FLAG M2 mAb, shows more rapid

10   killing than a culture of PRIESS cells induced into apoptosis using anti-CD95 mAb. An Annexin V/PI staining technique identifies necrotic cells by Annexin V positive and PI positive staining. b) Comparison of apoptosis induced in PRIESS cells after anti-DR and anti-CD95 mAb treatment. Incubation of PRIESS cells with the anti-HLA-DR antibody fragment MS-

15   GPC-8, cross-linked using the anti-FLAG M2 mAb, shows little evidence of an apoptotic mechanism compared to an apoptotic culture of PRIESS cells induced using anti-CD95 mAb. An Annexin V/PI staining technique identifies apoptotic cells by Annexin V positive and PI negative staining. c) Activated but not resting normal human B cells are killed by anti-DR mAb

20   treatment. B cells isolated from PBL by magnetic sorting (B Cell Isolation Kit, Miltenyi Biotec, Bergisch-Gladbach, Germany) were treated with 50 nM of different mAbs (unactivated), or stimulated with pokeweed mitogen (Gibco BRL) for 3 days (activated) and treated with mAbs subsequently.

Figure 9   a) Immunosuppressive properties of the IgG forms of the anti-HLA-DR

25   antibody fragments MS-GPC-8-10-57, MS-GPC-8-27-41 & MS-GPC-8-6-13 using an assay to determine inhibition of IL-2 secretion from T-hybridoma cells. b) Immunosuppressive properties of the monovalent Fab forms of the anti-HLA-DR antibody fragments MS-GPC-8-27-41 & MS-GPC-8-6-19 using an assay to determine inhibition of IL-2 secretion from T-

30   hybridoma cells. c) Secretion of IL-2 by T-cell hybridoma Hyb1 is inhibited by human and mouse HLA-DR mAb's. d) T-cell proliferation is inhibited by

mouse and human HLA-DR mAb's. e) T-cell proliferation stimulated by specific antigen hen egg lysozyme (HEL) is inhibited by mouse and human HLA-DR mAb's ex vivo. f) T-cell proliferation stimulated by specific antigen ovalbumin (OVA) is inhibited by mouse and human HLA-DR mAb's ex vivo. g) In vivo efficacy of human HLA-DR mAb's using the mouse model of delayed-type-hypersensitivity (DTH) induced by oxazolone (OXA) as measured by ear-thickness. h) Time course of *in vivo* efficacy of human HLA-DR mAb 1D09C3 in treating the mouse model of delayed-type-hypersensitivity (DTH) induced by dinitroflurobenzene (DNFB) as measured by ear-thickness. i) Dose response of *in vivo* efficacy of human HLA-DR mAb 1D09C3 in treating the mouse model of delayed-type-hypersensitivity (DTH) induced by dinitroflurobenzene (DNFB) as measured by ear-thickness.

Figure 10   Immunosuppressive properties of the IgG forms of the anti-HLA-DR antibody fragments MS-GPC-8-10-57 and MS-GPC-8-27-41 in an assay to determine inhibition of T cell proliferation.

Figure 11   Vector map and sequence of scFv phage display vector pMORPH13_scFv. The vector pMORPH13_scFv is a phagemid vector comprising a gene encoding a fusion between the C-terminal domain of the gene III protein of filamentous phage and a HuCAL scFv. In Figure 11, a vector comprising a model scFv gene (combination of VH1A and Vλ3 (Knappik et al., 2000) is shown. The original HuCAL master genes (Knappik et al. (2000): see Fig. 3 therein) have been constructed with their authentic N-termini: VH1A, VH1B, VH2, VH4 and VH6 with Q (=CAG) as the first amino acid. VH3 and VH5 with E (=GAA) as the first amino acid. Vector pMORPH13_scFv comprises the short FLAG peptide sequence (DYKD) fused to the VH chain, and thus all HuCAL VH chains in, and directly derived from, this vector have E (=GAA) at the first position (e.g. in pMx7_FS vector, see Figure 12).

Figure 12   Vector map and sequence of scFv expression vector pMx7_FS_5D2. The expression vector pMx7_FS_5D2 leads to the expression of HuCAL scFv fragments (in Figure 12, the vector comprises a gene encoding a "dummy"

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antibody fragment called "5D2") when VH-CH1 is fused to a combination of a FLAG tag (Hopp et al., 1988; Knappik and Plückthun, 1994) and a STREP tag II (WSHPQFEK) (IBA GmbH, Göttingen, Germany; see: Schmidt and Skerra, 1993; Schmidt and Skerra, 1994; Schmidt et al., 1996; Voss and Skerra, 1997).

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Figure 13   Vector map and sequence of Fab expression vector pMx9_Fab_GPC8. The expression vector pMx9_Fab_GPC8 leads to the expression of HuCAL Fab fragments (in Figure 13, the vector comprises the Fab fragment MS-GPC8) when VH-CH1 is fused to a combination of a FLAG tag (Hopp et al., 1988;

10   Knappik and Plückthun, 1994) and a STREP tag II (WSHPQFEK, SEQ ID No. 8) (IBA GmbH, Göttingen, Germany; see: Schmidt and Skerra, 1993; Schmidt and Skerra, 1994; Schmidt et al., 1996; Voss and Skerra, 1997). In pMx9_Fab vectors, the HuCAL Fab fragments cloned from the scFv fragments (see figure caption of Figure 11) do not have the short FLAG

15   peptide sequence (DYKD, SEQ ID No. 9) fused to the VH chain, and all HuCAL VH chains in, and directly derived from, that vector have Q (=CAG) at the first position

Figure 14   Vector map and sequence of Fab phage display vector pMORPH18_Fab_GPC8. The derivatives of vector pMORPH18 are

20   phagemid vectors comprising a gene encoding a fusion between the C-terminal domain of the gene III protein of filamentous phage and the VH-CH1 chain of a HuCAL antibody. Additionally, the vector comprises the separately encoded VL-CL chain. In Figure 14, a vector comprising the Fab fragment MS-GPC-8 is shown. In pMORPH18_Fab vectors, the HuCAL

25   Fab fragments cloned from the scFv fragments (see figure caption of Figure 11) do not have the short FLAG peptide sequence (DYKD, SEQ ID No. 9) fused to the VH chain, and all HuCAL VH chains in, and directly derived from, that vector have Q (=CAG) at the first position.

Figure 15   Amino acid sequences of VH and VL domains of MS-GPC-1, MS-GPC-6,
30   MS-GPC-8, MS-GPC-10, MS-GPC-8-6, MS-GPC-8-10, MS-GPC-8-17, MS-GPC-8-27, MS-GPC-8-6-13, MS-GPC-8-10-57, and MS-GPC-8-27-41.

The sequences in Figure 15 show amino acid 1 of VH as constructed in the original HuCAL master genes (Knappik et al. (2000): see Fig. 3 therein). In scFv constructs, as described in this application, amino acid 1 of VH is always E (see figure caption of Figure 11), in Fab constructs as described in this application, amino acid 1 of VH is always Q (see figure caption of Figure 13)

Figure 16.   *In vivo* effect of the human anti-DR mAb 1D09C3 in lymphoma xenograft models. a) survival of SCID mice injected s.c. with the non-Hodgkin lymphoma line GRANTA-519. MAb dose was 3x1 mg/mouse given on days 5, 7, and 9. Seven mice in the control and five in each mAb treated group. b) Effect of mAb on subcutaneous tumor growth. Same experiment as in a. c) Effect of mAb on disease incidence in SCID mice injected i.v. with GRANTA-519. MAb was administered i.v, 3x as above. Six mice were in each group.

Detailed Description of the Invention

The following examples illustrate the invention.

Examples

All buffers, solutions or procedures without explicit reference can be found in standard textbooks, for example Current Protocols of Immunology (1997 and 1999) or Sambrook et al., 1989. Where not given otherwise, all materials were purchased from Sigma, Deisenhofen, DE, or Merck, Darmstadt, DE, or sources are given in the literature cited. Hybridoma cell lines LB3.1 and L243 were obtained from LGC Reference Materials, Middlesex, UK; data on antibody 8D1 were generously supplied by Dr. Matyas Sandor, University of Michigan, Madison, WI, USA.

1.   Preparation of a human antigen

To demonstrate that we could identify cytotoxic antigen-binding domains of human composition, we first prepared a purified form of a human antigen, the human MHC class II DR protein (DRA*0101/DRB1*0401) from the DR-homozygous B-lymphoblastoid line PRIESS cells (Gorga et al., 1984; Gorga et al., 1986; Gorga et al.,

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1987; Stern et al., 1992) and the human-mouse chimeric molecule DR-I^E from the transfectant M12.C3.25 (Ito et al., *J. Exp. Med.* 183:2635-2644, 1996) by using standard methods of affinity purification (Gorga et al., 1984) as follows.

First, PRIESS cells (ECACC, Salisbury UK) were cultured in RPMI and 10% fetal calf serum (FCS) using standard conditions, and 10^{10} cells were lysed in 200 ml phosphate buffered saline (PBS) (pH 7.5) containing 1% NP-40 (BDH, Poole, UK), 25 mM iodoacetamide, 1 mM phenylmethylsulfonylfluoride (PMSF) and 10 mg/L each of the protease inhibitors chymostatin, antipain, pepstatin A, soybean trypsin inhibitor and leupeptin. The lysate was centrifuged at 10,000 x g (30 minutes, 4°C) and the resulting supernatant was supplemented with 40 ml of an aqueous solution containing 5% sodium deoxycholate, 5 mM iodoacetamide and 10 mg/L each of the above protease inhibitors and centrifuged at 100,000 x g for two hours (4°C). To remove material that bound non-specifically and endogenous antibodies, the resulting supernatant was made 0.2 mM with PMSF and passed overnight (4°C) through a rabbit serum affigel-10 column (5 ml; for preparation, rabbit serum (Charles River, Wilmington, MA, USA) was incubated with Affigel 10 (BioRad, Munich, DE) at a volume ratio of 3:1 and washed following manufacturer's directions) followed by a Protein G Sepharose Fast Flow column (2 ml; Pharmacia) using a flow rate of 0.2 ml/min.

Second, the pre-treated lysate was batch incubated with 5 ml Protein G Sepharose Fast Flow beads coupled to the murine anti-HLA-DR antibody LB3.1 (obtained by Protein G-Sepharose FF (Pharmacia) affinity chromatography of a supernatant of hybridoma cell line LB3.1) (Stern et al., 1993) overnight at 4°C using gentle mixing, and then transferred into a small column which was then washed extensively with three solutions: (1) 100 ml of a solution consisting of 50 mM Tris/HCl (pH 8.0), 150 mM NaCl, 0.5% NP-40, 0.5% sodium deoxycholate, 10% glycerol and 0.03% sodium azide at a flow rate of 0.6 ml/min). (2) 25 ml of a solution consisting of 50 mM Tris/HCl (pH 9.0), 0.5 M NaCl, 0.5% NP-40, 0.5% sodium deoxycholate, 10% glycerol and 0.03% sodium azide at a flow rate of 0.9 ml/min; (3) 25 ml of a solution consisting of 2 mM Tris/HCl (pH 8.0), 1% octyl-ß-D-glucopyranoside, 10% glycerol and 0.03% sodium azide at a flow rate of 0.9 ml/min.

Third, MHC class II DR protein (DRA*0101/DRB1*0401) was eluted using 15 ml of a solution consisting of 50 mM diethylamine/HCl (pH 11.5), 150 mM NaCl, 1 mM

EDTA, 1 mM EGTA, 1% octyl-ß-D-glucopyranoside (Alexis Corp., Lausen, CH), 10% glycerol, 10 mM iodoacetamide and 0.03% sodium azide at a flow rate of 0.4 ml/min. 800 μl fractions were immediately neutralised with 100 μl 1M Tris/HCl (pH 6.8), 150 mM NaCl and 1% octyl-ß-D-glucopyranoside. The incubation of the lysate with LB3.1-Protein

5   G Sepharose Fast Flow beads was repeated until the lysate was exhausted of MHC protein. Pure eluted fractions of the MHC class II DR protein (as analyzed by SDS-PAGE) were pooled and concentrated to 1.0 - 1.3 g/L using Vivaspin concentrators (Greiner, Solingen, DE) with a 30 kDa molecular weight cut-off. Approximately 1 mg of the MHC class II DR preparation was re-buffered with PBS containing 1% octyl-β-D-glucopyranoside using the

10   same Vivaspin concentrator to enable direct coupling of the protein to BIAcore CM5 chips.

2.   Screening of HuCAL

<u>2.1. Introduction</u>

Since the important biological activities of anti-DR mAbs, e.g., inhibition of CD4

15   T cell – antigen presenting cell (APC) interaction and tumoricide activity are associated with specificity for the first, N-terminal domains of DR molecules (Vidovic', D. et al., 1995, *Eur. J. Immunol.* 25:3349-3355), we used purified DR molecules as well as human-murine chimeric MHC-II molecules (DR first domains grafted onto a murine class II molecule, see Ito, K. et al., 1996, *J. Exp. Med.* 183:2635-2644) for screeining the Human

20   Combinatorial Antibody Library (HuCAL®) by alternating whole cell panning with protein solid-phase-panning.

We identified certain antigen binding antibody fragments (in this case, scFvs) of human composition (MS-GPC-1 / scFv-17, MS-GP-6 / scFv-8A, MS-GPC-8 / scFv-B8, MS-GPC-10 / scFv-E6, etc., see Figures 1 and 2) against the human antigen

25   (DRA*0101/DRB1*0401) from a human antibody library based on a novel concept that has been recently developed (Knappik et al., 2000). A consensus framework resulting in a total of 49 different frameworks here represents each of the VH- and VL-subfamilies frequently used in human immune responses. These master genes were designed to take into account and eliminate unfavorable residues promoting protein aggregation as well as

30   to create unique restriction sites leading to modular composition of the genes. In HuCAL-

scFv, both the VH- and VL-CDR3 encoding regions of the 49 master genes were randomized.

2.2. Phagemid rescue, phage amplification and purification

The HuCAL-scFv (Knappik et al., 2000) library, cloned into a phagemid-based phage display vector pMORPH13_scFv (see Figure 11), in *E. coli* TG-1 was amplified in 2 x TY medium containing 34 µg/ml chloramphenicol and 1% glucose (2 x TY-CG). After helper phage infection (VCSM13) at 37°C at an OD_{600} of about 0.5, centrifugation and resuspension in 2 x TY / 34 µg/ml chloramphenicol / 50 µg/ml kanamycin / 0.1 mM IPTG, cells were grown overnight at 30°C. Phage were PEG-precipitated from the supernatant (Ausubel et al., 1998), resuspended in PBS/20% glycerol and stored at −80°C. Phage amplification between two panning rounds was conducted as follows: mid-log phase TG1-cells were infected with eluted phage and plated onto LB-agar supplemented with 1% of glucose and 34 µg/ml of chloramphenicol. After overnight incubation at 30°C colonies were scraped off, adjusted to an OD_{600} of 0.5 and helper phage added as described above.

2.3. Manual solid phase panning

Wells of MaxiSorp™ microtiterplates (Nunc, Roskilde, DK) were coated with MHC- class II DRA*0101/DRB1*0401 (prepared as above) dissolved in PBS (2 µg/well). After blocking with 5% non-fat dried milk in PBS, 1–5 x 10^{12} HuCAL-scFv phage purified as above were added for 1h at 20°C. After several washing steps, bound phages were eluted by pH-elution with 100 mM triethylamine and subsequent neutralization with 1 M Tris-Cl pH 7.0. Three rounds of panning were performed with phage amplification conducted between each round as described above.

2.4. Mixed solid phase/whole cell panning

Three rounds of panning and phage amplification were performed as described in 2.3. and 2.2. with the exception that in the second round between 1 x 10^7 and 5 x 10^7 PRIESS cells in 1 ml PBS/10% FCS were used in 10 ml Falcon tubes for whole cell panning. After incubation for 1h at 20°C with the phage preparation, the cell suspension was centrifuged (2,000 rpm for 3 min) to remove non-binding phage, the cells were washed three times with 10 ml PBS, each time followed by centrifugation as described. Phage that specifically bound to the cells were eluted off by pH-elution using 100 mM

HCl. Alternatively, binding phage could be amplified by directly adding *E. coli* to the suspension after triethlyamine treatment (100 mM) and subsequent neutralization.

2.5 Identification of HLA-DR binding scFv fragments

Clones obtained after three rounds of solid phase panning (2.3) or mixed solid phase / whole cell panning (2.4) were screened by FACS analysis on PRIESS cells for binding to HLA-DR on the cell surface. For expression, the scFv fragments were cloned via *XbaI* / *EcoRI* into pMx7_FS as expression vector (see Figure 12). Expression conditions are shown below in example 3.2

Aliquots of 10^6 PRIESS cells were transferred at 4°C into wells of a 96-well microtiterplate. ScFv in blocking buffer (PBS / 5% FCS) were added for 60 min and detected using an anti-FLAG M2 antibody (Kodak) (1:5000 dilution) followed by a polyclonal goat anti-mouse IgG antibody-R-Phycoerythrin-conjugate (Jackson ImmunoResearch, West Grove, PA, USA, Cat. No. 115-116-146, F(ab')₂ fragment) (1:200 dilution). Cells were fixed in 4% paraformaldehyde for storage at 4°C. 10^4 events were collected for each assay on the FACS-Calibur (BD Immunocytometry Systems, San Jose, CA, USA).

Only fifteen out of over 500 putative binders were identified which specifically bound to PRIESS cells. Twelve scFv-s also bound to the chimeric MHC-II molecule, but showed no reactivity to either I-E^d (the murine part of chimeric MHC-II27), or unrelated proteins, such as lysozyme, transferrin, bovine serum albumine and human gamma globuline (Figure 1), indicating that they were specific for the first domains of DR molecules. Some of these clones were further analysed for their immunomodulatory ability and for their killing activity as described below. Table 1 contains the sequence characteristics of clones MS-GPC-1 (scFv-17), MS-GPC-6 (scFv-8A), MS-GPC-8 (scFv-B8) and MS-GPC-10 (scFv-E6) identified thereby. The VH and VL families and the CDR3s listed refer to the HuCAL consensus-based antibody genes as described (Knappik et al., 2000); the sequences of the VH and VL CDRs are shown in Table 1, and the full sequences of the VH and VL domains are shorn in Figure 15.

The fine specificity of scFv-s was tested on a panel of DR-homozygous typing cells, and MHC-II transfectants. Ten of 12 scFv-s reacted with all major allelic froms of

DR represented in the cell panel (DR1 through 14), and 4 of 12 recognized additional MHC-II molecules (DRw52 and w53, DP and DQ molecules; Figure 2). Thus, these antibodies potentially could be used widely as therapeutic agents across human populations virtually irrespective of polymorphic differences in MHC-II molecules. Most importantly, four of the 12 hits exhibited strong tumor killing activity, when cross-linked with anti-tag antibody (see Figure 2, in bold). The monovalent fragments were not tumoricidal, corresponding to previous observations (Vidovic', D. et al., 1995, *Eur. J. Immunol.* 25:3349-3355).

3.   Generation of Fab-fragments

3.1. Conversion of scFv to Fab

Since the tumoricidal hits had modest affinities (K_d-s ranging from 346 nM to 81 µM in single chain Fv (scFv) format), they were subjected to "in vitro affinity maturation". The parental scFv-s were first converted into Fab format that is less prone to aggregation and hence should give more reliable K_{off} values.

The Fab-fragment antigen binding polypeptides MS-GPC-1-Fab / 17-Fab, MS-GP-6-Fab / 8A-Fab, MS-GPC-8-Fab / B8-Fab and MS-GPC-10-Fab / E6-Fab were generated from their corresponding scFv fragments as follows. Both heavy and light chain variable domains of scFv fragments were cloned into pMx9_Fab (Figure 13), the heavy chain variable domains as *MfeI / StyI* -fragments, the variable domains of the kappa light chains as *EcoRV / BsiWI* - fragments. The lambda chains were first amplified from the corresponding pMORPH13_scFv vector as template with PCR-primers CRT5 (5' primer) and CRT6 (3' primer), wherein CRT6 introduces a unique *DraIII* restriction endonuclease site.

CRT5 (SEQ ID No. 10):

5' GTGGTGGTTCC*GATATC* 3'

CRT6 (SEQ ID No. 11):

5' AGCGTCAC*ACTCGGTGC*GGCTTTCGGCTGGCCAAGAACGGGTTA 3'

The PCR product is cut with *EcoRV / DraIII* and cloned into pMx9_Fab (see Figure 13). The Fab light chains could be detected with a polyclonal goat anti-human IgG

antibody-R-Phycoerythrin-conjugate (Jackson ImmunoResearch, West Grove, PA, USA, Cat. No. 109-116-088, F(ab')$_2$ fragment) (1:200 dilution).

3.2. Expression and purification of HuCAL-antibody fragments in *E. coli*

Expression in *E. coli* cells (JM83) of scFv and Fab fragments from pMx7_FS or pMx9_Fab, respectively, were carried out in one litre of 2 x TY-medium supplemented with 34 µg/ml chloramphenicol. After induction with 0.5 mM IPTG (scFv) or 0.1 mM IPTG (Fab), cells were grown at 22°C for 12 hours. Cell pellets were lysed in a French Press (Thermo Spectronic, Rochester, NY, USA) in 20 mM sodium phosphate, 0.5 M NaCl, and 10 mM imidazole (pH 7.4). Cell debris was removed by centrifugation and the clear supernatant filtered through 0.2 µm pores before subjecting it to STREP tag purification using a Streptactin matrix and purification conditions according to the supplier (IBA GmbH, Göttingen, Germany). Purification by size exclusion chromatography (SEC) was performed as described by Rheinnecker et al. (1996). The apparent molecular weights were determined by SEC with calibration standards and confirmed in some instances by coupled liquid chromatography-mass spectrometry (TopLab GmbH, Martinsried, Germany).

4.   Optimization of antibody fragments

In order to optimize certain biological characteristics of the HLA-DR binding antibody fragments, one of the Fab fragments, MS-GPC-8-Fab / B8-Fab, was used to construct a library of Fab antibody fragments by replacing the parental VL λ1 chain by the pool of all lambda chains λ 1-3 randomized in CDR3 from the HuCAL library (Knappik et al., 2000).

In the first round of optimization, both H-CDR2- and L-CDR3-sequences of clones MS-GPC-1 / scFv-17, MS-GPC-6 / scFv-8A, MS-GPC-8 / scFv-B8 and MS-GPC-10 / scFv-E6 were randomized by substituting the parental sequence with randomized TRIM®-based oligonucleotide-cassettes (Virnekäs et al., 1994) leading to four different libraries with 7.6 x 10^6 to 1.0 x 10^7 primary transformants.

For generation of H-CDR2 and L-CDR1-libraries: Trinucleotide-containing oligonucleotides starting from O-methyl trinucleotide phosphoramidites (Virnekäs 1994) were synthesized as described (Knappik et al., 2000). The VH2-CDR2-design comprised

an olionucleotide encoding for 16 amino acids which was randomized with up to 19 different amino acids (all except for cystein) at the following positions (from N- to C-terminus; amino acid-diversity and ratios in% are given in parentheses): position-1 (19), -2 (40% V / 20% D, F, N), -3 (40% V / 20% D, V, N), -4 (19), -5 (19), -6 (D), -7 (19), -8 (K),

5   -9 (19), -10 (Y), -11 (70% S / 30% G), -12 (50% P / 50% T), -13 (S), -14 (L), -15 (K), -16 (S). For the L-CDR1 of the lambda-1-framework two different oligonucleotides (termed as a and b) were designed to encode: a) position-1 (S), -2 (G), -3 (S), -4 (19), -5 (S), -6 (80% N / 10% D, K), -7 (I), -8 (G), -9 (19), -10 (19), -11 (19), -12 (V), -13 (19); b) position 1 (50% S, T), -2 (G), -3 (S), -4 (80% S / 20% N), -5 (S), 6 (N), -7 (I), -8 (G), -9 (19), -10

10   (19), -11 (19), -12 (19), -13 (V), -14 (19). The oligonucleotide for the CDR1 of lambda-2 framework was designed to encode: position-1 (19), -2 (G), -3 (S), -4 (89% S / 20% T), -5 (S), -6 (D), -7 (80% V, 20% I), -8 (G),) -9 (19), -10 (Y), -11 (19), -12 (19), -13 (V), -14 (19). For framwork lambda 3 the following CDR1-design was made: position-1 (33% G, Q, S), -2 (G), -3 (50% D, N), -4 (19), -5 (50% L, I), -6 (33% G, P, R), -7 (19), -8 (19), -9

15   (19), -10 (50% A, V), -11 (19). All cassettes were introduced into a promoter-less derivative of pMorph4 (Pack *et al.,* in preparation). For all subsequent affinity-maturations the respective H-CDR2 or L-CDR1-cassettes were derived from those plasmids using the respective flanking restriction-nuclease sites as described (Knappik et al., 2000). Prior to cloning of different libraries for affinity maturation all parental scFv were converted into

20   the Fab-format following the standard conversion protocol (Krebs et al., 2001) for the modular HuCAL®-library. Based on each of the 4 parental Fabs 17, 8A, B8 and E6 (all H2 lambda1) a sub-library was constructed exhibiting a repertoire of different L-CDR3- and H-CDR2-cassettes. First cloning step included the subsitution of the parental *XbaI / DraIII*-fragment of Fabs 17, B8, and E6 by a mix of corresponding fragments of all 3 V

25   lambda consensus-genes encoding a repertoire of 5.7×10^6 different L-CDR3 cassettes. Library-sizes for all 3 parental clones were in the range of $5.1 - 6.0 \times 10^6$ transformants. These libraries were then used to introduce different H-CDR2-library cassettes *via* substitution of the *XhoI / EagI*-fragments. Final library sizes resulted in up to 1.2×10^7 transformants including 78% correct clones based on DNA-sequence analyis. In case of

30   8A the LCDR3 optimization was performed by exchanging the parental *XbaI / BsiWI-* fragment for the corresponding HuCAL-scFv kappa3 sublibrary fragments. As before, this library was then used to insert different HCDR2-cassettes *via* the Xho/BssHII-fragment.

Library sizes were in the range of 1.7 x 10^6 cfu after L-CDR3- and 1.0 x 10^7 cfu after H-CDR2-cassette insertion including at least 65% correct clones according to DNA-sequence analysis. A fifth library has been constructed based on a consensus-sequence within H-CDR3 of binders 17, B8 and E6. For this purpose parental Fab B8 has been chosen to

5 randomize several positions within H-CDR3 by insertion of a synthetic TRIM-oligonucleotide comprising the following H-CDR3-design from N- to C-terminus: position 1 (all = all exept C), -2 (all), -3 (all), -4 (25% of Y/W/F/H), -4 (R), -5 (G), -6 (50% G/A), -7 (50% F/L), -8 (all). Final library size was in the range of 6.8 x 10^6 different transformants comprising 63% correct clones after sequence analysis.

10 L-CDR1-libraries were generated based on a pool of 20 different Fab-clones derived from the combined light-chain- and H-CDR2-based-optimization. Equimolar amounts of vector DNA from each parental clone was mixed after removal of the EcoRV/BpuAI-insert and religated by insertion of the corresponding fragments encoding a repertoire of different L-CDR1-cassettes. Final library-sizes were in the range of 4.2 x 10^8

15 cfu.

Since clones 17, B8 and E6 exhibited a consensus-motif in H-CDR3, a fifth library was constructed based on the parental clone B8, in which several H-CDR3 positions were randomized while keeping the consensus motif constant. The latter library termed B8M gave rise to 6.8 x 10^6 initial transformants. All libraries were subjected to either two

20 rounds of standard solid-phase panning on purified DR, or a solid phase and a whole cell panning.

Several panning-parameters including decreasing amounts of antigen (500 ng and 250 ng/well purified protein, see Schier et al., 1996a and 1996b), or increasing concentrations of NH$_4$SCN (50 mM, 250 mM, 500 mM in PBS) (Hall and Heckel 1988;

25 MacDonald 1988; Goldblatt 1993; Ferreira & Katzin 1995), or increasing the numbers of wash-cycles (Chen 1999; Low 1996) were applied in the second panning-round to enhance panning-stringency and hence the probability of selecting high affinity Fabs. Phage-antibodes derived from the first round of a manual solid-phase-panning on 250 and 500 ng/well purified HLA-protein, respecitvely, were pooled and used for the second panning

30 round on either 12 ng/well purified protein according to a standard protocol (Krebs et al., 2001), or on 250 ng coated antigen in combination with an additional 30 min incubation-

step of different amounts of ammonium-isothiocyanate (50 mM, 250 mM, 500 mM and in PBS) inbetween the standard wash-protocol (5 x TBST short and 5 x TBST for 5 min at room temperature) and the elution step (100 mM glycine-HCl / 500 mM NaCl, pH 2.2). Alternatively, the second panning round was performed on different amounts of PRIESS-

5 cells ranging from 10^1 - 10^5 cells/well according to a standard whole-cell-panning-protocol (Krebs et al., 2001). Fab-clones for K_{off} rankings were selected only from those panning wells which prior to and after treatment show a significant drop in phage-titer and thus indicating a maximum in bound phages at the highest panning-stringency.

For example, the Fab fragment MS-GPC-8-Fab / B8-Fab (see 3.1) was cloned via

10 *XbaI / EcoRI* from pMx9_Fab_GPC-8 into pMORPH18_Fab, a phagemid-based vector for phage display of Fab fragments, to generate pMORPH18_Fab_GPC-8 (see Figure 14). A lambda chain pool comprising a unique *DraIII* restriction endonuclease site (Knappik et al., 2000) was cloned into pMORPH18_Fab_GPC-8 cut with *NsiI* and *DraIII* (see vector map of pMORPH18_Fab_GPC-8 in Figure 14).

15 The resulting Fab optimization library was screened by two rounds of panning against MHC-class II DRA*0101/DRB1*0401 (prepared as above) as described in 2.3 with the exception that in the second round the antigen concentration for coating was decreased to 12 ng/well. FACS identified optimized clones as described above in 2.5.

Finally, 12 Fabs with improved K_{off} values were selected from the B8, B8M and

20 8A libraries. The best clone identified (MS-GPC-8-17 / 7BA) had a K_d of about 58 nM, corresponding to a 5-fold affinity improvement compared to the best unoptimized clone MS-GPC-8 / B8 (Table 3e). Libraries 17, E6 and 8A did not yield many clones with improved K_{off} values. Binders selected from the B8 library showed different L-CDR3-sequences, but all maintained the parental H-CDR2-sequence (Knappik et al., 2000),

25 suggesting that the latter is critical for antibody-antigen interaction. For further affinity-improvement, we focussed on binders from the B8 and B8M library.

Seven of these clones, MS-GPC-8-1, MS-GPC-8-6, MS-GPC-8-9, MS-GPC-8-10, MS-GPC-8-17 / 7BA, MS-GPC-8-18 and MS-GPC-8-27, were further characterized and showed cell killing activity as found for the starting fragment MS-GPC-8 / B8. Table 1

30 contains the sequence characteristics of MS-GPC-8-1, MS-GPC-8-6, MS-GPC-8-9, MS-GPC-8-10, MS-GPC-8-17 / 7BA, MS-GPC-8-18 and MS-GPC-8-27. The VH and VL

families and the CDR3s listed refer to the HuCAL consensus-based antibody genes as described (Knappik et al., 2000). The full sequences of the VH and VL domains of MS-GPC-8-6, MS-GPC-8-10, MS-GPC-8-17 / 7BA and MS-GPC-8-27are shown in Figure 15.

The optimized Fab forms of the anti-HLA-DR antibody fragments MS-GPC-8-6 and MS-GPC-8-17 showed improved characteristics over the starting MS-GPC-8 / B8. For example, the EC_{50} of the optimized antibodies was 15-20 and 5-20 nM (compared to 20-40 nM for MS-GPC-8 / B8, where the concentration is given as the concentration of the bivalent cross-linked Fab dimer), and the maximum capacity to kill MHH-Call 4 cells determined as 76 and 78% for MS-GPC-8-6 and MS-GPC-8-17 (compared to 65% for MS-GPC-8) respectively.

In the second round, L-CDR1-optimization is performed. The L-CDR1 library was generated from a pool of the 20 best Fab clones, of which 16 (including 7BA) derived from the L-CDR3 optimization and 4 from the H-CDR3 optimzation. To force off-rate selection, prolonged wash cycles and competing antigen were applied to the pool-library.

Specifically, the VL CDR1 regions of a set of anti-HLA-DR antibody fragments derived from MS-GPC-8 / B8 (including MS-GPC-8-10 and MS-GPC-8-27) were optimized by cassette mutagenesis using trinucleotide-directed mutagenesis (Virnekäs et al., 1994). In brief, a VλI CDR1 library cassette was synthesized containing six randomized positions (total variability: 7.43×10^6), and was cloned into a VλI framework. The CDR1 library was digested with EcoRV and BbsI, and the fragment comprising the CDR1 library ligated into the lambda light chains of the MS-GPC-8-derived Fab antibody fragments in pMORPH18_Fab (as described above), digested with EcoRV and BbsI. The resulting library was screened as described above.

The pool-library was subjected to two rounds of standard manual solid-phase panning using decreasing amounts of antigen (250 ng and 7.5 ng/well purified protein) or increasing concentrations of NH_4SCN (100 mM, 500 mM and 2500 mM), using either 2-fold serial dilutions of purified HLA-protein between 250 ng and 7.5 ng/well, or alternatively, constant amounts of 250 ng/well of protein in combination with an additional 30 min incubation step of different amounts of ammonium-isothiocyanate (100 mM, 500 mM and 2500 mM) between the standard wash-protocol and the elution step. In order to enforce off-rate-selection an additional manual solid-phase-panning of 3 selection rounds

was performed with the pool-library using 250 ng/well of coated HLA-protein in combination with longer washes (starting from 6 x 30 min in the first up to 24 x 30 min in the 3rd panning-round) and including different amounts of competing antigen (from 20 nM up to 500 nM) in the wash-buffer.

5   This strategy yielded Fabs with affinities of ~3 nM (Table 3e). Ten clones were identified as above by binding specifically to HLA-DR (MS-GPC-8-6-2, MS-GPC-8-6-19, MS-GPC-8-6-27, MS-GPC-8-6-45, MS-GPC-8-6-13 / 305D3, MS-GPC-8-6-47, MS-GPC-8-10-57 / 1C7277, MS-GPC-8-27-7, MS-GPC-8-27-10 & MS-GPC-8-27-41 / 1D09C3) and showed cell killing activity as found for the starting fragments MS-GPC-8,

10   MS-GPC-8-10 and MS-GPC-8-27. Table 1 contains the sequence characteristics of MS-GPC-8-6-2, MS-GPC-8-6-19, MS-GPC-8-6-27, MS-GPC-8-6-45, MS-GPC-8-6-13, MS-GPC-8-6-47, MS-GPC-8-10-57, MS-GPC-8-27-7, MS-GPC-8-27-10 & MS-GPC-8-27-41. The VH and VL families and the CDR3s listed refer to the HuCAL consensus-based antibody genes as described (Knappik et al., 2000), the full sequences of the VH and VL

15   domains of MS-GPC-8-6-13, MS-GPC-8-10-57 and MS-GPC-8-27-41 are shown in Figure 15.

From these 10 clones, four Fab fragments were chosen (MS-GPC-8-6-2, MS-GPC-8-6-13 / 305D3, MS-GPC-8-10-57 / 1C7277 and MS-GPC-8-27-41 / 1D09C3) as demonstrating significantly improved EC$_{50}$ of cell killing as described in example 10.

20   Table 1 shows the sequences of clones optimised at the CDR1 region.

Optimisation procedures not only increased the biological efficacy of anti-HLA-DR antibody fragments generated by the optimisation process, but a physical characteristic - affinity of the antibody fragment to HLA-DR protein - was also substantially improved. For example, the affinity of Fab forms of MS-GPC-8 / B8 and its optimised descendents

25   was measured using a surface plasmon resonance instrument (Biacore, Upsala Sweden) according to example 7. The affinity of the MS-GPC-8 / B8 parental Fab was improved over 100 fold from 346 nM to ~ 60 nM after VL CDR3 optimisation and further improved to single digit nanomolar affinity (range 3 – 9 nM) after VL CDR3+1 optimisation (Table 2).

30   *5.   Generation of IgG*

5.1 Construction of HuCAL-immunoglobulin expression vectors

Three Fabs (305D3, 1D09C3, and 1C7277) obtained above were converted into IgG$_4$ format, expressed and purified for affinity determination (see below). All 3 IgG$_4$ mAbs exhibited sub-nanomolar affinities (0.3-0.6 nM; Table 3e), and retained their specificity (Figure 2).

Heavy chains were cloned as follows. The multiple cloning site of pcDNA3.1+ (Invitrogen) was removed (*NheI* / *ApaI*), and a stuffer compatible with the restriction sites used for HuCAL-design was inserted for the ligation of the leader sequences (*NheI* / *EcoRI*), VH-domains (*EcoRI* / *BlpI*) and the immunoglobulin constant regions (*BlpI* / *ApaI*). The leader sequence (EMBL M83133) was equipped with a Kozak sequence (Kozak, 1987). The constant regions of human IgG$_1$ (PIR J00228), IgG$_4$ (EMBL K01316) and serum IgA$_1$ (EMBL J00220) were dissected into overlapping oligonucleotides with lengths of about 70 bases. Silent mutations were introduced to remove restriction sites non-compatible with the HuCAL-design. The oligonucleotides were spliced by overlap extension-PCR.

Light chains were cloned as follows. The multiple cloning site of pcDNA3.1/Zeo+ (Invitrogen) was replaced by two different stuffers. The κ-stuffer provided restriction sites for insertion of a κ-leader (*NheI* / *EcoRV*), HuCAL-scFv Vκ-domains (*EcoRV* / *BsiWI*) and the κ-chain constant region (*BsiWI* / *ApaI*). The corresponding restriction sites in the λ-stuffer were *NheI* / *EcoRV* (λ-leader), *EcoRV* / *HpaI* (Vλ- domains) and *HpaI* / *ApaI* (λ-chain constant region). The κ-leader (EMBL Z00022) as well as the λ-leader (EMBL L27692) were both equipped with Kozak sequences. The constant regions of the human κ- (EMBL J00241) and λ -chain (EMBL M18645) were assembled by overlap extension-PCR as described above.

5.2 Generation of IgG-expressing CHO-cells

All cells were maintained at 37°C in a humidified atmosphere with 5% CO$_2$ in media recommended by the supplier. CHO-K1 (CRL-9618) were from ATCC and were co-transfected with an equimolar mixture of IgG heavy and light chain expression vectors. Double-resistant transfectants were selected with 600 μg/ml G$_{418}$ and 300 μg/ml Zeocin (Invitrogen) followed by limiting dilution. The supernatant of single clones was assessed

for IgG expression by capture-ELISA. Positive clones were expanded in RPMI-1640 medium supplemented with 10% ultra-low IgG-FCS (Life Technologies). After adjusting the pH of the supernatant to 8.0 and sterile filtration, the solution was subjected to standard protein A column chromatography (Poros 20A, PE Biosystems).

5   The IgG forms of anti-HLA-DR antigen binding domains show improved characteristics over the antibody fragments. These improved characteristics include affinity (Example 7) and killing efficiency (Examples 9, 10 and 14).

6. HLA-DR specificity assay and epitope mapping

        To demonstrate that antigen-binding domains selected from the HuCAL library
10   bound specifically to a binding site on the N-terminal domain of human MHCII receptor largely conserved between alleles and hitherto unknown in the context of cell killing by receptor cross linking, we undertook an assessment of their binding specificity, and it was attempted to characterise the binding epitope.

        The Fab antibody fragments MS-GPC-8-27-7, MS-GPC-8-27-10, MS-GPC-8-6-13,
15   MS-GPC-8-27-41 / 1D09C3, MS-GPC-8-6-47, MS-GPC-8-10-57 / 1C7277, MS-GPC-8-6-27, MS-GPC-8 / B8 and MS-GPC-8-6 showed specificity of binding to HLA-DR protein but not to non-HLA-DR proteins. Fab fragments selected from the HuCAL library were tested for reactivity with the following antigens: HLA-DR protein (DRA*0101/DRB1*0401; prepared as example 1, and a set of unrelated non-HLA-DR
20   proteins consisting of BSA, testosterone-BSA, lysozyme and human apotransferrin. An empty well (Plastic) was used as negative control. Coating of the antigen MHCII was performed over night at 1 μg/well in PBS (Nunc-MaxiSorp TM) whereas for the other antigens (BSA, Testosterone-BSA, Lysozyme, Apotransferrin) 10 μg/well was used. Next day wells were blocked in 5% non-fat milk for 1 hr followed by incubation of the
25   respective antibodies (anti-MHCII-Fabs and an unrelated Fab (Mac1-8A)) at 100 ng/well for 1 hour. After washing in PBS the anti-human IgG F(ab')$_2$-peroxidase-conjugate at a 1:10,000 dilution in TBS (supplemented with 5% w/v non-fat dry-milk / 0.05% v/v Tween 20) was added to each well for 1h. Final washes were carried out in PBS followed the addition the substrate POD (Roche). Color-development was read at 370 nM in an ELISA-
30   Reader.

All anti-HLA-DR antibody fragments MS-GPC-8-27-7, MS-GPC-8-27-10, MS-GPC-8-6-13, MS-GPC-8-27-41, MS-GPC-8-6-47, MS-GPC-8-10-57, MS-GPC-8-6-27, MS-GPC-8 and MS-GPC-8-6 demonstrated high specificity for HLA-DR, as evidenced by the much higher mean fluorescence intensity resulting from incubation of these antibody

5   fragments with HLA-DR derived antigens compared to controls (Figure 1a). In a similar experiment, the Fab fragments MS-GPC-1, MS-GPC-6, MS-GPC-8 and MS-GPC-10 were found to bind to both the DRA*0101/DRB1*0401 (preparaed as above) as well as to a chimeric DR-IE consisting of the N-terminal domains of DRA*0101 and DRB1*0401 with the remaining molecule derived from a murine class II homologue IEd (Ito et al.,

10   1996) (Figure 1b).

To demonstrate the broad-DR reactivity of anti-HLA-DR antibody fragments and IgGs of the invention, the scFv forms of MS-GPC-1, 6, 8 and 10, and IgG forms of MS-GPC-8, MS-GPC-8-10-57, MS-GPC-8-27-51 & MS-GPC-8-6-13 were tested for reactivity against a panel of Epstein-Barr virus transformed B cell lines obtained from ECACC

15   (Salisbury UK), each homozygous for one of the most frequent DR alleles in human populations (list of cell lines and alleles shown in Figure 2). The antibody fragments were also tested for reactivity against a series of L cells transfected to express human class II isotypes other than DRB1: L105.1, L257.6, L25.4, L256.12 & L21.3 that express the molecules DRB3*0101, DRB4*0101, DP0103/0402, DP 0202/0201, and DQ0201/0602

20   respectively (Klohe et al., 1988).

Reactivity of an antigen-binding fragment to the panel of cell-lines expressing various MHC- class II molecules was demonstrated using an immunofluorescence procedure as for example, described by Otten et al (1997). Staining was performed on 2×10^5 cells using an anti-FLAG M2 antibody as the second reagent against the M2 tag

25   carried by each anti-HLA-DR antibody fragment and a fluorescein labelled goat anti-mouse Ig (BD Pharmingen, Torrey Pine, CA, USA) as a staining reagent. Cells were incubated at 4°C for 60 min with a concentration of 200 nM of the anti-HLA-DR antibody fragment, followed by the second and third antibody at concentrations determined by the manufacturers. For the IgG form, the second antibody was omitted and the IgG detected

30   using a FITC-labeled mouse anti-human IgG_4 (Serotec, Oxford, UK) . Cells were washed

between incubation steps. Finally the cells were washed and subjected to analysis using a FACS Calibur (BD Immunocytometry Systems, San Jose, CA, USA).

Figure 2 shows that the scFv-fragments MS-GPC-1, 6, 8 and 10, and IgG forms of MS-GPC-8, MS-GPC-8-10-57, MS-GPC-8-27-51 & MS-GPC-8-6-13 react with all DRB1 allotypes tested. This observation taken together with the observation that all anti-HLA-DR antibody fragments react with chimeric DR-IE, suggests that all selected anti-HLA-DR antibody fragments recognize the extracellular first domain of the monomorphic DRα chain or a monomorphic epitope on extracellular first domain of the DRβ chain.

We then attempted to localize the binding domains of MS-GPC-8-10-57 and MS-GPC-8-27-41 further by examining competitive binding with murine antibodies for which the binding domains on HLA-DR are known. The murine antibodies L243 and LB3.1 are known to bind to the α1 domain, 1-1C4 and 8D1 to the β1 domain and 10F12 to the β2 domain (Vidovic et al. 1995b). To this end, an assay was developed wherein a DR-expressing cell line (LG-2) was at first incubated with the IgG_4 forms of MS-GPC-8-10-57 or MS-GPC-8-27-41, the Fab form of MS-GPC-8-10-57 or the Fab form of GPC 8, and an unrelated control antibody. Subsequently murine antibodies were added and the murine antibodies were detected. If the binding site of MS-GPC-8-10-57 or MS-GPC-8-27-41 overlaps with the binding of a murine antibody, then a reduced detection of the murine antibody is expected.

Binding of the IgG_4 forms of GPC-8-27-41 and MS-GPC-8-10-57 and the Fab form of MS-GPC-8-10-57 substantially inhibited (mean fluorescence intensity reduced by > 90%) the binding of 1-1C4 and 8D1, whereas L243, LB3.1 and 10F12 and a control were only marginally affected. The Fab form of MS-GPC-8 reduced binding of 1-1C4 by ~ 50% (mean fluorescence dropped from 244 to 118), abolished 8D1 binding and only marginally affected binding of L243, LB3.1 and 10F12 or the control. An unrelated control antibody had no effect on either binding. Thus, MS-GPC-8-10-57 and MS-GPC-8-27-41 seem to recognise a β1 domain epitope that is highly conserved among allelic HLA-DR molecules.

The whole staining procedure was performed on ice. 1×10^7 cells of the human B-lymphoblastoid cell line LG-2 was preblocked for 20 min. in PBS containing 2% FCS and 35 µg/ml Guinea Pig IgG ("FACS-Buffer"). These cells were divided into 3 equal parts A,

B, and C of approximately 3.3 x 10^6 cells each, and it was added to A) 35 μg MS-GPC-8-10-57 or MS-GPC-8-27-41 IgG$_4$, to B) 35 μg MS-GPC-8-10-57 Fab or MS-GPC-8 Fab, and to C) 35 μg of an unrelated IgG$_4$ antibody as negative control, respectively, and incubated for 90 min. Subsequently A, B, C were divided in 6 equal parts each containing

5   5.5 x 10^5 cells, and 2 μg of the following murine antibodies were added each to one vial and incubated for 30 min: 1) purified mIgG ; 2) L243; 3) LB3.1; 4) 1-1 C4; 5) 8D1; 6) 10F12. Subsequently, 4 ml of PBS were added to each vial, the vials were centrifuged at 300 x g for 8 min, and the cell pellet resuspended in 50 μl FACS buffer containing a 1 to 25 dilution of a goat-anti-murine Ig-FITC conjugate at 20 μg/ml final concentration (BD

10   Pharmingen, Torrey Pines, CA, USA). Cells were incubated light-protected for 30 min. Afterwards, cells were washed with 4 ml PBS, centrifuged as above and resuspended in 500 μl PBS for analysis in the flow cytometer (FACS Calibur, BD Immunocytometry Systems, San Jose, CA, USA).

The PepSpot technique (US 6,040,423; Heiskanen et al., 1999) is used to further

15   identify the binding epitope for MS-GPC 8-10-57. Briefly, an array of 73 overlapping 15-mer peptides is synthesised on a cellulose membrane by a solid phase peptide synthesis spotting method (WO 00/12575). These peptide sequences are derived from the sequence of the α1 and ß1 domains of HLA-DR4Dw14, HLA-DRA1*0101 (residues 1-81) and HLA-DRB1*0401 (residues 2-92), respectively, and overlap by two amino acids. Second,

20   such an array is soaked in 0.1% Tween-20/PBS (PBS-T), blocked with 5% BSA in PBS-T for 3 hours at room temperature and subsequently washed three times with PBS-T. Third, the prepared array is incubated for 90 minutes at room temperature with 50 ml of a 5 mg/l solution of the IgG form of GPC-8-10-57 in 1% BSA/PBS-T. Fourth, after binding, the membrane is washed three times with PBS-T and subsequently incubated for 1 hour at

25   room temperature with a goat anti-human light chain antibody conjugated to horseradish peroxidase diluted 1/5,000 in 1% BSA/PBS-T. Finally, the membrane is washed three times with PBS-T and any binding determined using chemiluminescence detection on X-ray film. As a control for unspecific binding of the goat anti-human light chain antibody, the peptide array is stripped by the following separate washings each at room temperature

30   for 30 min: PBS-T (2 times), water, DMF, water, an aequeous solution containing 8 M urea, 1% SDS, 0.5% DTT, a solution of 50% ethanol, 10% acetic acid in water (3 times each) and, finally, methanol (2 times). The membrane is again blocked, washed, incubated

with goat anti-human 1 light chain antibody conjugated to horseradish peroxidase and developed as described above.

7. *Affinity of anti- HLA-DR antibody and antibody fragments*

In order to demonstrate the superior binding properties of anti-HLA antibody fragments of the invention, we measured their binding affinities to the human MHC class II DR protein (DRA*0101/DRB1*0401) using standard equipment employing plasmon resonance principles. Surprisingly, we achieved affinities in the sub-nanomolar range for IgG forms of certain anti-HLA-DR antibody fragments of the invention. For example, the affinity of the IgG forms of MS-GPC-8-27-41, MS-GPC-8-6-13 & MS-GPC-8-10-57 was measured as 0.3, 0.5 and 0.6 nM respectively (Table 3a). Also, we observed high affinities in the range of 2-8 nM for Fab fragments affinity matured at the CDR1 and CDR3 light chain regions (Table 3b). Fab fragments affinity matured at only the CDR3 light chain region showed affinities in the range of 40 to 100 nM (Table 3c), and even Fab fragments of non-optimised HuCAL antigen binding domains showed affinities in the sub μM range (Table 3d). Only a moderate increase in K_{on} (2-fold) was observed following CDR3 optimisation (K_{on} remained approximately constant throughout the antibody optimization process in the order of 1×10^5 $M^{-1}s^{-1}$), whilst a significant decrease in K_{off} was a surprising feature of the optimisation process – sub 100 s^{-1}, sub 10 s^{-1}, sub 1 s^{-1} and sub 0.1 s^{-1} for the unoptimised Fabs, CDR3 optimised Fabs, CDR3/CDR1 optimised Fabs and IgG forms of anti-HLA-DR antibody fragments of the invention.

The affinities for anti-HLA antibody fragments of the invention were measured as follows. All measurements were conducted in HBS buffer (20 mM HEPES, 150 mM NaCl, pH 7.4) at a flow rate of 20 μl/min at 25°C on a BIAcore3000 instrument (Biacore AB, Sweden). MHC class II DR protein (prepared as example 1) was diluted in 100 mM sodium acetate pH 4.5 to a concentration of 50 - 100 mg/ml, and coupled to a CM5 chip (Biacore AB) using standard EDC-NHS coupling chemistry with subsequent ethanolamine treatment as manufacturers directions. The coating density of MHCII was adjusted to between 500 and 4000 RU. Affinities were measured by injection of 5 different concentrations of the different antibodies and using the standard software of the Biacore instrument. Regeneration of the coupled surface was achieved using 10 mM glycine pH 2.3 and 7.5 mM NaOH.

8.   Multivalent killing activity of anti HLA-DR antibodies and antibody fragments

To demonstrate the effect of valency on cell killing, a cell killing assay was performed using monovalent, bivalent and multivalent compositions of anti-HLA-DR antibody fragments of the invention against GRANTA-519 cells. Anti-HLA-DR antibody

5   fragments from the HuCAL library showed much higher cytotoxic activity when cross-linked to form a bivalent composition (60 – 90% killing at antibody fragment concentration of 200 nM) by co-incubation with anti-FLAG M2 mAb (Figure 3) compared to the monovalent form (5 – 30% killing at antibody fragment concentration of 200 nM). Incubation of cell lines alone or only in the presence of anti-FLAG M2 mAb without co-

10   incubation of anti-HLA-DR antibody fragments did not lead to cytotoxicity as measured by cell viability. Treatment of cells as above but using 50 nM of the IgG_4 forms (naturally bivalent) of the antibody fragments MS-GPC-8, MS-GPC-8-6-13, MS-GPC-8-10-57 and MS-GPC-8-27-41 without addition of anti-FLAG M2 mAb showed a killing efficiency after 4 hour incubation of 76%, 78%, 78% and 73% respectively.

15   Furthermore, we observed that higher order valences of the anti-HLA-DR antibody fragments further decrease cell viability significantly. On addition of Protein G to the incubation mix containing the IgG form of the anti-HLA-DR antibody fragments, the multivalent complexes thus formed further decrease cell viability compared to the bivalent composition formed from incubation of the anti-HLA-DR antibody fragments with only

20   the bivalent IgG form.

The killing efficiency of anti-HLA-DR antibody fragments selected from the HuCAL library was tested on the HLA-DR positive tumor cell line GRANTA-519 (DSMZ, Germany). 2×10^5 cells were incubated for 4 h at 37°C under 6% CO_2 with 200 nM anti-HLA-DR antibody fragments in RPMI 1640 (PAA, Germany) supplemented with

25   2.5% heat inactivated FBS (Biowhittaker Europe, BE), 2 mM L-glutamine, 1% non-essential amino acids, 1 mM sodium pyruvate and 0.1 mg/ml kanamycin. Each anti-HLA-DR antibody fragment was tested for its ability to kill activated tumor cells as a monovalent anti-HLA-DR antibody fragment or as a bivalent composition by the addition of 100 nM of a bivalent cross-linking anti-FLAG M2 mAb. After 4 h incubation at 37°C

30   under 6% CO_2, cell viability was determined by trypan blue staining and subsequent counting of remaining viable cells (Current Protocols in Immunology, 1997).

The above experiment was repeated using KARPAS-422cells against a multivalent form of IgG forms of MS-GPC-8-10-57 and MS-GPC-8-27-41 prepared by a pre-incubation with a dilution series of the bacterial protein Protein G. Protein G has a high affinity and two binding sites for IgG antibodies, effectively cross-linking them to yield a total binding valency of 4. In a control using IgG alone without preincubation with Protein G, approximately 55% of cells were killed, while cell killing using IgG pre-incubated with Protein G gave a maximum of approximately 75% at a molar ratio of IgG antibody / Protein G of ~ 6 (based on a molecular weight of Protein G of 28.5 kD). Higher or lower molar ratios of IgG antibody/Protein G approached the cell killing efficiency of the pure IgG antibodies.

9.   Killing efficiency of anti-HLA-DR antibody fragments

Experiments to determine the killing efficiency of the anti-HLA-DR cross-linked antibody fragments against other tumor cell lines that express HLA-DR molecules were conducted analogous to example 8. Tumor cell lines that show greater than 50% cell killing with the cross linked Fab form of MS-GPC-8 after 4 h incubation include MHH-CALL4, MN 60, BJAB, BONNA-12 which represent the diseases B cell acute lymphoid leukemia, B cell acute lymphoid leukemia, Burkitt lymphoma and hairy cell leukemia respectively. Use of the cross-linked Fab form of the anti-HLA-DR antibody fragments MS-GPC-1, 6 and 10 also shows similar cytotoxic activity to the above tumor cell lines when formed as a bivalent agent using the cross-linking anti-FLAG M2 mAb.

The method described in example 8 was used to determine the maximum killing capacity for each of the cross-linked bivalent anti-HLA-DR antibody fragments against PRIESS cells. The maximum killing capacity observed for MS-GPC-1, MS-GPC-6, MS-GPC-8 & MS-GPC-10 was measured as 83%, 88%, 84% and 88% respectively. Antibody fragments generated according to example 4, when cross linked using anti-FLAG M2 mAb as above, also showed improved killing ability against GRANTA and PRIESS cells (Table 4).

10.   Killing efficiency of anti-HLA-DR IgG antibodies of human composition

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The optimized IgG$_4$ mAbs were tested for induction of tumor cell death on a panel of 24 DR$^+$ and 4 DR$^-$ cell lines, representing a variety of lymphoma/leukemia types (Table 5). Compared to corresponding murine antibodies (Vidovic et al, 1995b; Nagy & Vidovic, 1996; Vidovic & Toral; 1998), we were surprised to observe significantly improved killing efficiency of IgG forms of certain anti-HLA-DR antibody fragments of the invention (Table 5). The killing is dependent on HLA-DR expression, but is HLS-DR subtype independent.

For the cell killing assay, cells at 2×10^6/ml concentration were incubated in RPMI 1640 supplemented with 2.5% fetal calf serum (Biowhittaker Europe, Belgium) and different concentrations (50 nM in most experiments) of human anti-DR mAb at 37°C for 4hrs (and 24h in some experiments). Control cultures were without mAb or with a murine anti-DR mAb 10F12 that fails to induce cell death. Cell cultures were set up in duplicate in flat bottom 96 well plates. Since dead cells disintegrate very fast (within 30 min),% killing was determined based on viable cell recovery as follows: (viable untreated − viable treated/viable untreated) x 100. Viable and dead cells were distinguished by trypan blue staining for light microscopy, fluorescein diacetate (FDA; 100 µg/ml final concentration; live cells) and propidium iodide (PI, 40 µg/ml final concentration; dead cells) for fluorescent microscopy, and PI for FACS analysis. To obtain absolute cell counts by FACS analysis, each culture was supplemented with equal amounts of FACS "Truecount" calibrating beads. Cell counts were determined by the formula: viable cells x total beads / counted beads. The three different methods of cell counting (light and fluorescent microscopy and FACS) yielded comparable results.

Following the method described in examples 8 and 9 and above but at 50 nM, repeated measurements (3 to 5 replica experiments where cell number was counted in duplicate for each experiment) were made of the killing efficiency of the IgG forms of certain antibody fragments of the invention.

The mAbs induced death in a wide range (23 of the 25) DR$^+$ lymphoid tumor lines. When applied at a final concentration of only 50 nM, IgGs of the antibody fragments MS-GPC-8 / B8, MS-GPC-8-6-13 / 305D3, MS-GPC-8-10-57 / 1C7277 & MS-GPC-8-27-41 / 1D09C3 killed more than 50% of cells from 17, 20, 19 and 22 respectively of a panel of 25 human tumor cell lines that express HLA-DR antigen at a level greater than 10 fluorescent

units as determined by example 11. For comparison, two murine anti-DR mAbs, L243 (Vidovic et al, 1995b) and 8D1 (Vidovic & Toral; 1998) known to induce cell death[7,10] were tested on the same panel at 4 fold higher concentration (200 nM) than the human mAbs. The murine mAbs usually killed less cells than human mAbs, or failed to induce

5   death in some DR[+] lines. Over all, they reduced cell viability to a level below 50% viable cells in only 13 and 12 of the 25 HLA-DR expressing cells lines, respectively.

In direct comparisons, the human mAbs achieved 50% killing efficiency at 20 to 30 fold lower concentrations than the murine mAbs (see below). Statistical analysis of the data in Table 5 revealed a non-linear correlation between killing efficiency and the level of

10   DR expression, with a significantly greater killing efficiency and better correlation for the human mAbs because of the failure of the murine mAbs to kill a number of DR[+] lines.

Indeed, even at the significantly increased concentration, the two murine antibodies treated at 200 nM showed significantly less efficient killing compared to the IgG forms of anti-HLA-DR antibody fragments of the invention. Not only do IgG forms of the human

15   anti-HLA-DR antibody fragments of the invention show an overall increase in cell killing at lower concentrations compared to the murine antibodies, but they show less variance in killing efficiency across different cell lines. The coefficient of variance in killing for the human antibodies in this example is 32% (mean% killing = 68 +/- 22% (SD)), compared to over 62% (mean% killing = 49 +/- 31% (SD)) for the mouse antibodies. Statistically

20   controlling for the effect on killing efficiency due to HLA expression by fitting logistic regression models to mean percentage killing against log(mean HLA-DR expression) supports this observation (Figure 4). Not only is the fitted curve for the murine antibodies consitently lower than that for the human, but a larger variance in residuals from the murine antibody data (SD = 28%) is seen compared to the variance in residuals from the

25   human antibody data (16%). The superior performance of human mAbs could be explained, at least in part, by their higher affinity (K_d-s 0.3-0.6 nM, see Table 3e, compared to L243 10 nM, and 8D1 > 30 nM (Z.A. Nagy, unpublished)).

The cell line MHH-PREB-1 was singled out and not accounted as part of the panel of 25 cell lines despite its expression of HLA-DR antigen at a level greater than 10

30   fluorescent units due to the inability of any of the above antibodies to induce any significant reduction of cell viability. This is further explained in example 12.

The viability of DR⁻ cell lines was not significantly affected.

11. Killing selectivity of antigen-binding domains against a human antigen for activated versus non-activated cells

Since MHC-II molecules are constitutively expressed on B lymphocytes, the most obvious potential side effect of anti-DR mAb treatment would be the killing of normal B cells. Human peripheral B cells were therefore used to demonstrate that human anti-HLA-DR mAb-mediated cell killing is dependent on cell-activation. 50 ml of heparinised venous blood was taken from an HLA-DR typed healthy donor and fresh peripheral blood mononuclear cells (PBMC) were isolated by Ficoll-Hypaque Gradient Centrifugation (Histopaque-1077; Sigma) as described in Current Protocols in Immunology (John Wiley & Sons, Inc.; 1999). Purified B cells (~5% of peripheral blood leukocytes) were obtained from around 5×10^7 PBMC using the B-cell isolation kit and MACS LS^+/VS^+ columns (Miltenyi Biotec, Germany) according to manufacturers guidelines. Successful depletion of non-B cells was verified by FACS analysis of an aliquot of isolated B cells (HLA-DR positive and CD19 positive). Double staining and analysis is done with commercially available antibodies (BD Immunocytometry Systems, San Jose, CA, USA) using standard procedures as for example described in Current Protocols in Immunology (John Wiley & Sons, Inc.; 1999). An aliquot of the isolated B cells was tested for the ability of the cells to be activated by stimulation with Pokeweed mitogen (PWM) (Gibco BRL, Cat. No. 15360-019) diluted 1:25 in RPMI 1640 (PAA, Germany) supplemented with 10% FCS (Biowhittaker Europe, BE), 2 mM L-glutamine, 1% non-essential amino acids, 1 mM sodium pyruvate and 0.1 mg/ml kanamycin by incubation at 37°C under 6% CO_2 for three days. Successful activation was verified by FACS analysis of HLA-DR expression on the cell surface (Current Protocols in Immunology, John Wiley & Sons, Inc.; 1999).

The selectivity for killing of activated cells versus non-activated cells was demonstrated by incubating 1×10^6 /ml B cells activated as above compared to non-activated cells, respectively with 50 nM of the IgG forms of MS-GPC-8-10-57, MS-GPC-8-27-41 or the murine IgG 10F12 (Vidovic et al., 1995b) in the medium described above but supplemented with 2.5% heat inactivated FCS instead of 10%, or with medium alone. After incubation at 37°C under 6% CO_2 for 1 or 4h, cell viability was determined by fluorescein diacetate staining (FDA) of viable and propidium iodide staining (PI) of dead

cells and subsequent counting of the green (FDA) and red (PI) fluorescent cells using a fluorescence microscope (Leica, Germany) using standard procedures (Current Protocols in Immunology, 1997).

B cell activation was shown to be necessary for cell killing. In non-activated cells after 1 hr of incubation with the anti-HLA-DR antibodies, the number of viable cells in the media corresponded to 81%, 117% 126% and 96% of the pre-incubation cell density for MS-GPC-8-10-57 (IgG), MS-GPC-8-27-41 (IgG), 10F12 and medium alone, respectively. In contrast, the number of viable activated B cells after 1 h incubation corresponded to 23%, 42% 83% and 66% of the pre-incubation cell density for MS-GPC-8-10-57 (IgG), MS-GPC-8-27-41 (IgG), 10F12 and medium alone, respectively. After 4 hr of incubation, 78%, 83% 95% and 97% of the pre-incubation cell density for MS-GPC-8-10-57 (IgG), MS-GPC-8-27-41 (IgG), 10F12 and medium alone were found viable in non-activated cells, whereas the cell density had dropped to 23%, 24% 53% and 67% of the pre-incubation cell density for MS-GPC-8-10-57 (IgG), MS-GPC-8-27-41 (IgG), 10F12 and medium alone, respectively, in activated cells.

In conclusion, as shown in Figure 8c, the viability of purified resting B cells was not significantly altered by human anti-DR mAbs. In contrast, pokeweed mitogen-activated B cells from the same donor were killed by these mAbs. No death of either unactivated or activated B cells was induced by the control antibody 10F12. Similar results were obtained with resting and lipopolysaccharide-stimulated spleenic B cells from DR-transgenic mice (Ito, K. et al. *J. Exp. Med.* 183:2635-2644, 1996) (data not shown). Thus, it appears that the mAbs can kill activated but not resting MHC-II positive normal cells in addition to tumor cells, suggesting a dual requirement of both MHC-II expression and cell activation for mAb-induced death. Since the majority (up to 99%) of peripheral B cells is resting, the potential side effect due to killing of normally activated B cells in a leukaemia patient is negligible.

12. Killing activity of anti-HLA antibody fragments against the cell line MHH PreB 1

As evidenced in Table 5, we observed that our cross-linked anti-HLA-DR antibody fragments or IgGs did not readily kill a particular tumor cell line expressing HLA-DR at significant levels (MHH-PREB-1). We hypothesized that although established as a stable

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cell line, cells in this culture were not sufficiently activated. We therefore stimulated these cells with interferon-gamma, and lipopoysaccharide. Activation was evidenced by an increase in the cell surface expression of CD40 and HLA-DR.

Non-adherently growing MHH preB1 cells were cultivated in RPMI medium containing the following additives (all from Gibco BRL and Bio Whittaker): 10% FCS, 2 mM L-glutamine, 1% non-essential amino acids, 1 mM sodium pyruvate and 1 x Kanamycin. Aliquots were activated to increase expression of HLA-DR molecule by incubation for one day with Lipopolysaccharide (LPS, 10 µg/ml), Interferon-gamma (IFN-γ, Roche, 40 ng/ml) and phyto-hemagglutinin (PHA, 5 µg/ml). The cell surface expression of HLA-DR molecules was monitored by flow cytometry with the FITC-conjugated mAb L243 (BD Immunocytometry Systems, San Jose, CA, USA). Incubation of MHH preB1 for one day in the presence of LPS, IFN-γ and PHA resulted in a 2-fold increase in HLA-DR surface density (mean fluorescence shift from 190 to 390). Cell killing was performed for 4 hrs in the above medium but containing a reduced FCS concentration (2.5%). A concentration series of the IgG forms of MS-GPC-8-27-41 / 1D09C3 & MS-GPC-8-10-57 / 1C7277 was employed, consisting of final antibody concentrations of 3300, 550, 92, 15, 2.5, 0.42 and 0.07 nM, on each of an aliquot of non-activated and activated cells. Viable cells were identified microscopically by exclusion of Trypan blue. Whereas un-activated cell viability remains unaffected by the antibody up to the highest antibody concentration used, cell viability is dramatically reduced with increasing antibody concentration in activated MHH PreB1 cells (Figure 5).

In addition, we found that cell proliferation was apparently not needed, since tumor cells in mitosis-arrest remained susceptible to mAb-mediated killing (data not shown).

In contracts to the mAbs we describe here, two additional anti-HLA-DR mAbs with therapeutic potential, Lym-1 (Epstein et al., Cancer Res. 47:830-840, 1987; DeNardo et al., Int. J. Cancer 96 (suppl.3):96, 1988) and 1D10 (Gingrich et al., Blood 75:2375-2387, 1990), achieve selectivity in a different way. These two mAbs recognize what appear to be posttranslational modifications on DR molecules that occur preferentially in B-cell derived tumors, although some expression was noted also on normal B cells and monocytes(Epstein et al., 1987; DeNardo et al., 1988). Neither of these mAbs has inherent tumoricidal activity, and thus, Lym-1 is developed in a ^{131}I-labelled form (Oncolym®),

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whereas the efficacy of 1D10 relies on intact immunological effector mechanisms of the patient, similarly to other mAbs (Vose et al., *J. Clin. Oncol.* 19:389-397, 2001; Dyer et al., *Blood* 73:1431-1439, 1989) already available for the clinic. Furthermore, Lym-1 is a murine mAb with substantial immunogenicity for humans, and 1D10 is a humanized murine mAb. Our fully human mAbs with strong inherent tumoricidal activity and selectivity for activated / tumor transformed cells demonstrate a substantially different profile and mechanism of action from these two mAbs, and thus promise a novel therapeutic approach to lymphoma / leukemia.

13. Killing efficiency of anti-HLA-DR IgG antibodies of human composition against ex-vivo chronic lymphoid leukemia cells

We investigated whether the human anti-DR mAbs would also be active on freshly isolated leukemic cells, in addition to established cell lines. Using purified malignant B cells obtained from the peripheral blood of 10 un-typed chronic lymphoid leukemia (CLL) patients (Buhmann et al., *Blood* 93:1992-2002, 1999), we demonstrated that IgG forms of anti-HLA-DR antibody fragments of the invention showed efficacy in killing of clinically relevant cells using an *ex-vivo* assay (Figure 6). Although the killing kinetics are slightly slower than those of *in vitro* experiments using established cell lines, significant killing is achieved over 24 hours of Ab incubation, despite the low rate of CLL cell proliferation.

B-cells were isolated and purified from 10 unrelated patients suffering from CLL (samples kindly provided by Prof Hallek, Ludwig Maximillian University, Munich) according to standard procedures (Buhmann et al., (1999)). 2 x 10^5 cells were treated with 100 nM of IgG forms of the anti-HLA-DR antibody fragments MS-GPC-8, MS-GPC-8-10-57 or MS-GPC-8-27-41 and incubated for 4 or 24 hours analogous to examples 8 and 9. A replica set of cell cultures was established and activated by incubation with HeLa-cells expressing CD40 ligand on their surface for three days before treatment with antibody (Buhmann et al., 1999). As controls, the murine IgG 10F12 (Vidovic et al., 1995b) or no antibody was used. Cell viability for each experiment was determined as described in example 12.

Surprisingly, IgG forms of the anti-HLA-DR antibody fragments of the invention showed highly efficient and uniform killing - even across this diverse set of patient

material. After only 4 hours of treatment, all three human IgGs gave a significant reduction in cell viability compared to the controls, and after 24 hours only 33% of cells remained viability (Figure 6). We found that on stimulating the *ex-vivo* cells further according to Buhmann et al. (1999), the rate of killing was increased such that after only 4 hours culture

5   with the human antibodies, only 24% of cells remained viable on average for all patient samples and antibody fragments of the invention. The control murine anti-DR mAb 10F12, which has no inherent tumoricidal activity (Vidovic', D. et al., *Eur. J. Immunol.* 25:3349-3355, 1995), had no effect on CLL cells (Figure 6c).

14. Determination of EC_{50} for anti-HLA-DR antibody fragments

10   We demonstrated superior Effective Concentration at 50% effect (EC_{50}) values in a cell-killing assay for certain forms of anti-HLA-DR antibody fragments selected from the HuCAL library compared to cytotoxic murine anti-HLA-DR antibodies (Table 6).

The EC_{50} for anti-HLA-DR antibody fragments selected from the HuCAL library were estimated using the HLA-DR positive cell line PRIESS or LG2 (ECACC, Salisbury

15   UK). 2 x 10^5 cells were incubated for 4 h at 37°C under 6% CO_2 in RPMI 1640 (PAA, Germany) supplemented with 2.5% heat inactivated FBS (Biowhittaker Europe, BE), 2 mM L-glutamine, 1% non-essential amino acids, 1mM sodium pyruvate and 0.1 mg/ml kanamycin, together with dilution series of bivalent anti-HLA-DR antibody fragments. For the dilution series of Fab antibody fragments, an appropriate concentration of Fab

20   fragment and anti-FLAG M2 antibody were premixed to generate bivalent compositions of the anti-HLA-DR antibody fragments. The concentrations stated refer to the concentration of bivalent composition such that the IgG and Fab EC_{50} values can be compared.

After 4 h incubation with bivalent antibody fragments at 37°C under 6% CO_2, cell viability was determined by fluorescein diacetate staining and subsequent counting of

25   remaining viable cells (Current Protocols in Immunology, 1997). Using standard statistical software, non-linear logistic regression curves were fitted to replica data points and the EC_{50} estimated for each antibody fragment.

When cross-linked using the anti-FLAG M2 antibody, the Fab fragments MS-GPC-1, MS-GPC-8 & MS-GPC-10 selected from the HuCAL library (Example 4) showed

30   an EC_{50} of less than 120 nM as expressed in terms of the concentration of the monovalent

fragments, which corresponds to a 60 nM EC_{50} for the bivalent cross-linked (Fab)dimer-anti-Flag M2 conjugate. (Figure 7a). When cross-linked using the anti-FLAG M2 antibody, anti-HLA-DR antibody fragments optimised for affinity within the CDR3 region (Example 4) showed a further improved EC_{50} of less than 50 nM, or 25 nM in terms of the

5   bivalent cross-linked fragment (Figure 7b), and those additionally optimised for affinity within the CDR1 region showed an EC_{50} of less than 30 nM (15 nM for bivalent fragment). In comparison, the EC_{50} of the cytotoxic murine anti-HLA-DR antibodies 8D1 (Vidovic & Toral; 1998) and L243 (Vidovic et al; 1995b) showed an EC_{50} of over 30 and 40 nM, respectively, within the same assay (Figure 7c).

10   Surprisingly, the IgG form of certain antibody fragments of the invention showed approximately 1.5 orders of magnitude improvement in EC_{50} compared to the murine antibodies (Figure 7d). For example, the IgG forms of MS-GPC-8-10-57 & MS-GPC-8-27-41 showed an EC_{50} of 1.2 and 1.2 nM respectively. Furthermore, despite being un-optimised for affinity, the IgG form of MS-GPC-8 showed an EC_{50} of less than 10 nM.

15   As has been shown in examples 11 and 12, the efficiency of killing of un-activated cells (normal peripheral B and MHH PreB cells respectively) is very low. After treatment with 50 nM of the IgG forms of MS-GPC-8-10-57 & MS-GPC-8-27-41, 78% and 83% of normal peripheral B cells, respectively, remain viable after 4 hours. Furthermore, at only 50 nM concentration or either IgG, virtually 100% viability is seen for MHH PreB1 cells.

20   Indeed, a decrease in the level of viability to below 50% cannot be achieved with these un-activated cells using reasonable concentration ranges (0.1 to 300 nM) of IgG or bivalent cross-linked Fab forms of the anti-HLA-DR antibody fragments of the invention. Therefore, the EC_{50} for these un-activated cell types can be estimated to be at least 5 times higher than that shown for the non-optimised Fab forms ($EC_{50} \sim 60$ nM with respect to cross-linked bivalent fragment), and at least 10 times and 100 times higher than EC_{50}s

25   shown for the VHCDR3 optimised Fabs (~ 25 nM with respect to cross-linked bivalent fragment) and IgG forms of MS-GPC-8-10-57 ($\sim$1.2 nM) & MS-GPC-8-27-41 ($\sim$1.2 nM) respectively.

15. Mechanism of cell-killing

The examples described above show that cell death occurs - needing only certain multivalent anti-HLA-DR antibody fragments to cause killing of activated cells. No further cytotoxic entities or immunological mechanisms were needed to cause cell death, therefore demonstrating that cell death is mediated through an innate pre-programmed mechanism of the activated cell. The mechanism of apoptosis is a widely understood process of pre-programmed cell death. We were surprised by certain characteristics of the cell killing we observed that suggested the mechanism of killing for activated cells when exposed to our human anti-HLA-DR antibody fragments was not what is commonly understood in the art as "apoptosis". For example, the observed rate of cell killing appeared to be significantly greater than the rate reported for apoptosis of immune cells (about 10 - 15 hrs; Truman et al., 1994). Two experiments were conducted to demonstrate that the mechanism of cell killing proceeded by a non-apoptotic mechanism.

First, we used Annexin-V-FITC and propidium iodide (PI) staining techniques to distinguish between apoptotic and non-apoptotic cell death – cells undergoing apoptosis, "apoptotic cells", (Annexin-V positive / PI negative) can be distinguished from necrotic ("Dead") (Annexin-V positive/PI positive) and fully functional cells (Annexin-V negative / PI negative). Using the procedures recommended by the manufacturers of the AnnexinV and PI assays, 1 x 10^6/ml PRIESS cells were incubated at 37°C under 6% CO_2 with or without 200 nM anti-HLA-DR antibody fragment MS-GPC-8 together with 100 nM of the cross-linking anti-FLAG M2 mAb in RPMI 1640 (PAA, DE) supplemented with 2.5% heat inactivated FCS (Biowhittaker Europe, BE), 2 mM L-glutamine, 1% non-essential amino acids, 1 mM sodium pyruvate and 0.1 mg/ml kanamycin. To provide an apoptotic cell culture as control, 1 x 10^6/ml PRIESS cells were induced to enter apoptosis by incubation in the above medium at 37°C under 6% CO_2 with 50 µg/ml of the apoptosis-inducing anti-CD95 mAb DX2 (BD Pharmingen, Torrey Pine, CA, USA) cross-linked with 10 µg/ml Protein-G. At various incubation times (1, 15 and 60 min., 3 and 5 hrs) 200 µl samples were taken, washed twice and stained with Annexin-V-FITC (BD Pharmingen, Torrey Pine, CA, USA) and PI using Annexin-V binding buffer following the manufacturer's protocol. The amount of staining with Annexin-V-FITC and PI for each group of cells is analysed with a FACS Calibur (BD Immunocytometry Systems, San Jose, CA, USA).

Cell death induced through the cross-linked anti-HLA-DR antibody fragments shows a significantly different pattern of cell death than that of the anti-CD95 apoptosis inducing antibody or the cell culture incubated with anti-FLAG M2 mAb alone. The percentage of dead cells (as measured by Annexin-V positive/PI positive staining) for the anti-HLA-DR antibody fragment/anti-FLAG M2 mAb treated cells increases far more rapidly than that of the anti-CD95 or the control cells (Figure 8a). In contrast, the percentage of apoptotic cells (as measured by Annexin-V positive/PI negative staining) increases more rapidly for the anti-CD95 treated cells compared to the cross-linked anti-HLA-DR antibody fragments or the control cells (Figure 8b).

Second, we inhibited caspase activity using zDEVD-fmk, an irreversible Caspase-3 inhibitor, and zVAD-fmk, a broad spectrum Caspase inhibitor (both obtained from BioRad, Munich, DE). The mechanism of apoptosis is characterized by activity of caspases, and we hypothesized that if caspases were not necessary for anti HLA-DR mediated cell death, we would observe no change in the viability of cells undergoing cell death in the presence of these caspase inhibitors compared to those without. 2×10^5 PRIESS cells were preincubated for 3 h at 37°C under 6% CO_2 with serial dilutions of the two caspase inhibitors ranging from 180 μM to 10 mM in RPMI 1640 (PAA, DE) supplemented with 2.5% heat inactivated FCS (Biowhittaker Europe, BE), 2mM L-glutamine, 1% non-essential amino acids, 1 mM sodium pyruvate and 0.1 mg/ml kanamycin. HLA-DR mediated cell death was induced by adding 200 nM of the human anti-HLA-DR antibody fragment MS-GPC-8 and 100 nM of the cross-linking anti-M2 mAb. An anti-CD95 induced apoptotic cell culture served as a control for the activity of inhibitors (Drenou et al., 1999). After further incubation at 37°C and 6% CO_2, cell viability after 4 and 24 h was determined by trypan blue staining and subsequent counting of non-stained cells. As we expected, cell viability of the anti-HLA-DR treated cell culture was not significantly modified by the presence of the Caspase inhibitors, while cell death induced through anti-CD95 treatment was significantly decreased for the cell culture pre-incubated with the Caspase inhibitors. We therefore concluded that the cell death induced by the human anti-DR mAbs does not occur via the classical apoptotic pathway that can be inhibited by zDEVD-fm or zVAD-fmk.

16. In vivo therapy for cancer using an HLA-DR specific antibody

To test the *in vivo* efficacy, we inoculated immunocompromised (such as scid, nude or Rag-1 knockout) SCID (severe combined immunodeficient) mice subcutaneously (s.c.) or intraveneously (i.v.) with the non-Hodgkin B cell lymphoma line GRANTA-519 (see in Table 5), and monitored tumor development in mice treated with mAb, in comparison to solvent-treated animals.

In general, mice are treated i.v. or s.c with the IgG form of the anti-HLA-DR antibody fragments MS-GPC-8, MS-GPC-8-10-57, MS-GPC-8-27-41 or others of the invention prepared as described above, using doses of 1 to 25 mg/kg over 5 days. Survival of anti-HLA-DR treated and control untreated mice is monitored for up to 8 weeks after cessation of treatment. Tumor progression in the mice inoculated s.c. is additionally quantified by measuring tumor surface area.

For example, eight weeks old female C.B.-17 scid mice were injected with anti-asialoGM1 antibody (Wako Chemicals, Neuss, Germany; 25 µl diluted 4 fold in PBS, i v.) to suppress natural killer (NK) cell activity, on days 0, 1, and 2. On day 1, $5x10^6$ GRANTA-519 cells were injected s.c. into the right flank, or i.v. The endpoint in the s.c. model is a tumor surface area of > 5 cm^2, skin ulceration above the tumor, or death, and in the i.v. model hind leg paralysis or death. Mice were treated with 1 mg or 0.2 mg 1D09C3 mAb s.c. or i.v. on days 5, 7 and 9. Control mice received PBS. Mice were monitored, and tumor length and width were measured by a slide-gauge twice a week.

Significant prolongation of survival of up to 80% of anti-HLA-DR treated mice is observed during the experiment, and up to 50% mice survive at the end of the experiment. In the s.c. tumor experiment, at day 48, 100% of s.c. mAb treated mice were alive and 80% of i.v. mAb treated mice were alive (death is not related to mAb treatment or tumor), while all control mice died within the observation period (Figure 16a). In s.c. inoculated and untreated mice, the tumor reaches a surface area of 2 - 3 cm^2, while in anti-HLA-DR treated animals the tumor surface area is significantly less. Figure 16d shows representative tumor size in mice treated or untreated by mAb of the instant invention. Tumor growth was also significantly retarded in the treated animals (Figure 16b). In the i.v. tumor experiment, a significant delay (about 30 days) in disease onset was observed in the mAb treated groups (Figure 16c). The 30 day survival rate for i.v. mAb treated mice is 100%, while the survival rate for control mice is 0%. Even at day 40, the survival rate for

i.v. mAb treated mice is 50% / 20% (for high / low doses, respectively). Tumor-induced paralysis is also significantly reduced in the i.v. mAb treated mice as compared to the control group mice which are all paralysized by day 40.

These experiments demonstrate that antigen-binding domains of human composition can successfully be used as a therapeutic for the treatment of cancer. The *in vitro*, *ex vivo* and *in vivo* efficacy data presented here are strong evidence that such mAbs offer the potential to become useful and potent therapeutic agents for the treatment of different DR^+ lymphoma and leukemia.

17. Immunosuppression using anti-HLA-DR antibody fragments measured by reduction in IL-2 secretion

Various diseases are caused by or associated with activated T-cells. For example, delayed-type hyper sensitivity (DTH) is caused by T-cells activated by antigen-presenting cells (APCs) via MHC receptors. Thus, inhibition of interaction between the MHC class II molecule and the T-cell receptor (TCR) can inhibit certain undesirable immune responses.

We were surprised to observe that certain anti-HLA-DR antibody fragments of the invention also displayed substantial immunomodulatory properties within an assay measuring IL-2 secretion from immortalized T-cells (T-cell hybridoma). IgG forms of the antibody fragments MS-GPC-8-6-13 / 305D3, MS-GPC-8-10-57 / 1C7277 & MS-GPC-8-27-41 / 1D09C3 showed very strong immunosuppressive properties in this assay with sub-nanomolar IC_{50} values and virtually 100% maximal inhibition (Figure 9a). Particularly surprising was our observation that certain monvalent compositions of the antibody fragments of the invention were able to strongly inhibit IL-2 secretion in the same assay. For example, Fab forms of the VH CDR3-selected and VL CDR3 / VL CDR1 optimised antibody fragments showed low single-digit nM IC_{50}'s and also almost 100% maximal inhibition (Figure 9b). Other monvalent anti-HLA-DR antibody fragments of the invention showed significant immunosuppressive properties in the assay compared to control IgG and Fab fragments (Table 7). Figure 9c also shows immunomodulatory properties of the mouse 1-2 C4 and L243 mAb as well as the GPC 1 and 2 Ab's.

The immunomodulatory properties of anti-HLA-DR antibody fragments was investigated by measuring IL-2 secretion from the hybridoma cell line T-Hyb1 stimulated

using DR-transgenic antigen presenting cells (APC) under conditions of half-maximal antigen stimulation. IL-2 secretion was detected and measured using a standard ELISA method provided by the OptiEIA mouse IL-2 kit of Pharmingen (Torrey Pine, CA, USA). APCs were isolated from the spleen of unimmunized chimeric 0401-IE transgenic mice (Ito et al. 1996) according to standard procedures. 1.5×10^5 APCs were added to 0.2 ml wells of 96-well in RPMI medium containing the following additives (all from Gibco BRL and PAA): 10% FCS, 2 mM L-glutamine, 1% non-essential amino acids, 1 mM sodium pyruvate and 0.1 g/l kanamycin. Hen egg ovalbumin was added to a final concentration of 200 μg/ml in a final volume of 100 ul of the above medium, the cells incubated with this antigen for 30 min at 37°C under 6% CO_2. Anti-HLA-DR antibody fragments were added to each well at various concentrations (typically in a range from 0.1 to 200 nM), the plate incubated for 1 h at 37°C / 6% CO_2 and 2×10^5 T-Hyb1 cells added to give a final volume of 200 μl in the above medium. After incubation for 24 h, 100 μl of supernatant was transferred to an ELISA plate (Nunc-Immuno Plate MaxiSorp surface, Nunc, Roskilde, DK) previously coated with IL-2 Capture Antibody (BD Pharmingen, Torrey Pine, CA, USA), the amount of IL-2 was quantified according to the manufacturer's directions using the OptiEIA Mouse IL-2 kit and the plate read using a Victor V reader (Wallac, Finland). Secreted IL-2 in pg/ml was calibrated using the IL-2 standards provided in the kit.

The T-cell hybridoma line T-Hyb1 was established by fusion of a T-cell receptor negative variant of the thymoma line BW 5147 (ATCC) and lymph node cells from chimeric 0401-IE transgenic mice previously immunized with hen egg ovalbumin (Ito et al. 1996). The clone T-Hyb1 was selected for the assay since it responded to antigen specific stimulation with high IL-2 secretion.

18. Immunosuppression using an HLA-DR specific antibody measured by T cell proliferation

Immunomodulatory properties of the anti-HLA-DR antibody fragments were also seen within an assay that measures T cell proliferation. The IC_{50} value for inhibition of T cell proliferation of the IgG form of MS-GPC-8-10-57 / 1C7277 and MS-GPC-8-27-41 / 1D09C3 were 11 and 20 nM respectively (Figure 10). The anti-HLA-DR antibody fragments were tested as follows to inhibit the proliferative T cell response of antigen-primed lymph node cells from mice carrying a chimeric mouse-human class II transgene

with an RA-associated peptide binding site, and lack murine class II molecules (Muller et al., 1990; Woods et al., 1994; Current Protocols in Immunology, Vol. 2, 7.21; Ito et al., 1996). Here, the immunization takes place *in vivo*, but the inhibition and readout are *ex vivo*. Transgenic mice expressing MHC class II molecules with binding sites of the RA associated molecule, DRB*0401 were commercially obtained. These mice lack murine MHC class II, and thus, all Th responses are channelled through a single human RA-associated MHC class II molecule (Ito et al., 1996). These transgenic mice represent a model for testing human class II antagonists.

The inhibitory effect of the anti-HLA-DR antibody fragments and their IgG forms were tested on T-cell proliferation measured using chimeric T-cells and antigen presenting cells isolated from the lymph nodes of chimeric 0401-I^E transgenic mice (Taconic, USA) previously immunized with hen egg ovalbumin (Ito et al., 1996) according to standard procedures. 1.5 x 10^5 cells are incubated in 0.2 ml wells of 96-well tissue culture plates in the presence of ovalbumin (30 µg per well - half-maximal stimulatory concentration) and a dilution series of the anti-HLA-DR antibody fragment or IgG form under test (0.1 nM - 200 nM) in serum free HL-1 medium containing 2 mM L-glutamine and 0.1 g/L Kanamycin for three days. Antigen specific proliferation is measured by ^{3}H-methyl-thymidin(1 µCi/well) incorporation during the last 16 hrs of culture (Falcioni et al., 1999). Cells are harvested, and ^{3}H incorporation measured using a scintillation counter (TopCount, Wallac Finland). Inhibition of T-cell proliferation on treatment with the anti-HLA-DR antibody fragment and its IgG form was observed by comparison to control wells containing antigen. Figure 9d showed that the proliferation of the T-cell line NG-TcL HA-10 was significantly inhibited by the two GPC antibodies (MS-GPC-8-10-57 / 1C7277 and MS-GPC-8-27-41 / 1D09C3), at least to the same extent of the mouse 1-1 C4 positive control Ab.

Figure 9e and 9f showed that transgenic T-cell proliferation as measured by ^{3}H incorporation in two experiments were significantly inhibited by mAb treatments, including MS-GPC-8-10-57 / 1C7277 and MS-GPC-8-27-41 / 1D09C3 human mAb's and mouse L243, 11C4 and LB3.1 Ab's. In these experiments, T-cells are sensitized *in vivo* by specific antigens (ovalbumin (OVA) in one case, hen egg lysozyme (HEL) in another case), followed by re-stimulation *ex vivo* by these two antigens respectively for measuring

immune stimulation in the form of antigen specific induction of T-cell proliferation. Figure 9e and 9f showed that more than 90% inhibition of antigen specific induction of T-cell proliferation is achieved using the human mAb's of the instant invention.

19. Selection of useful polypeptide for the treatment of cancers

5   In order to select the most appropriate protein/peptide to enter further experiments and to assess its suitability for use in a therapeutic composition for the treatment of cancers, additional data are collected. Such data for each IgG form of the anti-HLA antigen antibody fragments can include the binding affinity, *in vitro* killing efficiency as measured by EC_{50} and cytotoxicity across a panel of tumor cell lines, the maximal percentage cell 10   killing as estimated *in vitro*, and tumor reduction data and mouse survival data from *in vivo* animal models.

      The IgG form of the anti-HLA antigen antibody fragments that shows the highest affinity, the lowest EC_{50} for killing, the highest maximal percentage cell killing and broadest across various tumor cell lines, the best tumor reduction data and/or the best 15   mouse-survival data may be chosen to enter further experiments. Such experiments may include, for example, therapeutic profiling and toxicology in animals and phase I clinical trials in humans.

20. In vivo Efficacy of Immunosuppression using an HLA-DR specific antibody in treating Delayed-Type-Hypersensitivity (DTH)

20   In order to determine the *in vivo* efficacy of the immunosuppression activity of the mAb's of the instant invention, we conducted experiments using a mouse model for delayed-type-hypersensitivity (DTH). In this system, mouse ear-swelling in response to treatments by haptens such as oxazalone (OXA) or dinitroflurobenzene (DNFB) were measured to determine the in vivo efficacy of the mAb's of the instant invention.

25   Specifically, 0.05 ml of 2% OXA or DNFB were applied to the bellies of treatment group mice on day 1 and 2. On day 5, different doses of test mAb's 1D09C3 or control treatments were administered i.v. After waiting for 4 or 8 hours, mice were challenged with 0.02 ml of 0.5% OXA or DNFB. Ear thickness was measured on day 6, 8, 9 and 12, and the results were presented in Figure 9g, 9h and 9i.

In figure 9g, DTH to OXA as measured by ear-thickness was blocked by roughly 75% if 1 mg or 0.75 mg of mAb was administered i.v., while 0.5 mg of mAb or less has no significant effect.

In figure 9h, the time course of inhibition, by human anti-DR mAb, of DTH to DNFB in DR-tg mice as measured by ear-thickness was presented. DTH was almost completely blocked (P < 0.005) at 7th hour after treatment with the mAb 1D09C3, followed by a 60% block (P < 0.01) at 18th hr and no effect at 4 hr. Figure 9i showed a positive correlation between the dose of mAb (1D09C3) used at the 7th hour and the effectiveness of the inhibition of DTH in DR-tg mice. Both 1 mg and 0.5 mg of 1D09C3 significantly (P < 0.005) inhibited DTH while lower doses have no effect.

These experiments demonstrates that mAb's of the instant invention is capable of specifically inhibiting the very part of the immune system responsible for the unwanted immune reaction. It is an inhibition of immune reaction rather than suppression of existing immune reactios. Since the mAb's of the instant invention are fully human antibodies, rather than murine mAb or humanized murine antibodies, they are expected to have very low immunogenicity in the host and a much longer half life. In addition, most mAb's of the instant invention also have very high affinity in the pico molar range. These mAb's shall prove to be useful for a variety of immune diseases such as DTH and Graft v. Host Disease (GVHD).

21. Selection of useful polypeptide for the treatment of diseases of the immune system

In order to select the most appropriate protein/peptide to enter further experiments and to assess its suitability for use in a therapeutic composition for the treatment of diseases of the immune system, additional data are collected. Such data for each monovalent antibody fragment or IgG form of the anti-HLA antigen antibody fragments can include the affinity, reactivity, specificity, IC_{50}-values, for inhibition of IL-2 secretion and of T-cell proliferation, or *in vitro* killing efficiency as measured by EC_{50} and the maximal percentage cell killing as estimated *in vitro*, and DR-transgenic models of transplant rejection and graft vs. host disease.

The antibody fragment or IgG form of the anti-HLA antigen antibody fragments that shows the lowest EC_{50}, highest affinity, highest killing, best specificity and/or greatest

inhibition of T-cell proliferation or IL-2 secretion, and high efficacy in inhibiting transplant rejection and/or graft vs. host disease in appropriate models, might be chosen to enter further experiments. Such experiments may include, for example, therapeutic profiling and toxicology in animals and phase I clinical trials in humans.

SigA2

Table 1:

VH and VL families, VL CDR1 and VH/VL CDR 3 sequences of HLA-DR-specific polypeptides

Clone	VH	CDR3 Length	VH-CDR3-Seq.	VL	VL-CDR1-Seq.	CDR3 Length	VL-CDR3-Seq.	Families
MS-GPC-1	H2	10	QYGHRGGFDH	λ1	SGSSSNIGSNYVS	8	QSYDFNES	H2 λ1
MS-GPC-6	H3	9	GYGRYSPDL	K3	RASQSVSSSYLA	8	QQYSNLPF	H3 K3
MS-GPC-8	H2	10	SPRYRGAFDY	λ1	SGSSSNIGSNYVS	8	QSYDMPQA	H2 λ1
MS-GPC-10	H2	10	QLHYRGGFDL	λ1	SGSSSNIGSNYVS	8	QSYDLTMG	H2 λ1
MS-GPC-8-1	H2	10	SPRYRGAFDY	λ1	SGSSSNIGSNYVS	8	QSYDFSHY	H2 λ1
MS-GPC-8-6	H2	10	SPRYRGAFDY	λ1	SGSSSNIGSNYVS	8	QSYDYDHY	H2 λ1
MS-GPC-8-9	H2	10	SPRYRGAFDY	λ1	SGSSSNIGSNYVS	8	QSYDIQLH	H2 λ1
MS-GPC-8-10	H2	10	SPRYRGAFDY	λ1	SGSSSNIGSNYVS	8	QSYDLIRH	H2 λ1
MS-GPC-8-17	H2	10	SPRYRGAFDY	λ1	SGSSSNIGSNYVS	8	QSYDFSVY	H2 λ1
MS-GPC-8-18	H2	10	SPRYRGAFDY	λ1	SGSSSNIGSNYVS	8	QSYDFSIY	H2 λ1
MS-GPC-8-27	H2	10	SPRYRGAFDY	λ1	SGSSSNIGSNYVS	8	QSYDMNVH	H2 λ1
MS-GPC-8-6-2	H2	10	SPRYRGAFDY	λ1	SGSESNIGSNYVH	8	QSYDYDHY	H2 λ1
MS-GPC-8-6-19	H2	10	SPRYRGAFDY	λ1	SGSESNIGSNYVA	8	QSYDYDHY	H2 λ1
MS-GPC-8-6-27	H2	10	SPRYRGAFDY	λ1	SGSDSNIGANYVT	8	QSYDYDHY	H2 λ1

	H2	10		λ1		8		H2λ1
MS-GPC-8-6-45	H2	10	SPRYRGAFDY	λ1	SGSEPNIGSNYVF	8	QSYDYDHY	H2λ1
MS-GPC-8-6-13	H2	10	SPRYRGAFDY	λ1	SGSESNIGANYVT	8	QSYDYDHY	H2λ1
MS-GPC-8-6-47	H2	10	SPRYRGAFDY	λ1	SGSESNIGSNYVS	8	QSYDYDHY	H2λ1
MS-GPC-8-10-57	H2	10	SPRYRGAFDY	λ1	SGSESNIGNNYVQ	8	QSYDLIRH	H2λ1
MS-GPC-8-27-7	H2	10	SPRYRGAFDY	λ1	SGSESNIGNNYVG	8	QSYDMNVH	H2λ1
MS-GPC-8-27-10	H2	10	SPRYRGAFDY	λ1	SGSESNIGANYVN	8	QSYDMNVH	H2λ1
MS-GPC-8-27-41	H2	10	SPRYRGAFDY	λ1	SGSESNIGNNYVQ	8	QSYDMNVH	H2λ1

Table 2:

Steps in Antibody optimisation	Fab	k_{on} [s^{-1}M^{-1}] x 10^5 ±SD	k_{off} [s^{-1}] x 10^{-3} ±SD	K_D [nM] ±SD	L-CDR3	L-CDR1
Parental Fab	MS-GPC-8	0.99 ± 0.40	29.0 ± 8.40	346.1 ± 140.5[a)]	QSYDMPQA	SGSSSNIGSNYVS
L-CDR3-optim.	-8-1	1.93	20.9	108[e)]		
L-CDR3-optim.	-8-6	0.96 ± 0.14	5.48 ± 0.73	58.6 ± 11.7[b)]		
L-CDR3-optim.	-8-9	1.85	16.6	90.1[e)]		
L-CDR3-optim.	-8-10	nd	7.0[e)]	nd		
L-CDR3-optim.	-8-17	1.0	5.48	54.7[e)]		
L-CDR3-optim.	-8-18	1.06	8.3	78.3[e)]		
L-CDR3-optim.	-8-27	nd	6.6[e)]	nd		
L-CDR3-optim.	-8-6	0.96 ± 0.14	5.48 ± 0.73	58.6 ± 11.7[b)]	QSYDYDHY	SGSSSNIGSNYVS
L-CDR3+1-opt.	-8-6-2	1.23 ± 0.11	0.94 ± 0.07	7.61 ± 0.25[c)]	QSYDYDHY	SGSESNIGSNYVH
L-CDR3+1-opt.	-8-6-19	1.10 ± 0.08	0.96 ± 0.15	8.74 ± 1.33[c)]	QSYDYDHY	SGSESNIGSNYVA
L-CDR3+1-opt.	-8-6-27	1.80 ± 0.24	1.10 ± 0.15	6.30 ± 0.63[d)]	QSYDYDHY	SGSDSNIGANYVT
L-CDR3+1-opt.	-8-6-45	1.20 ± 0.07	1.03 ± 0.04	8.63 ± 0.61[c)]	QSYDYDHY	SGSEPNIGSNYVF
L-CDR3+1-opt.	-8-6-13	1.90 ± 0.26	0.55 ± 0.05	2.96 ± 0.46[c)]	QSYDYDHY	SGSESNIGANYVT
L-CDR3+1-opt.	-8-6-47	1.97 ± 0.29	0.62 ± 0.04	3.18 ± 0.33[c)]	QSYDYDHY	SGSESNIGSNYVS
L-CDR3+1-opt.	-8-10-57	1.65 ± 0.21	0.44 ± 0.06	2.67 ± 0.25[c)]	QSYDLIRH	SGSESNIGNNYVQ
L-CDR3+1-opt.	-8-27-7	1.74 ± 0.21	0.57 ± 0.07	3.30 ± 0.34[d)]	QSYDMNVH	SGSESNIGNNYVG
L-CDR3+1-opt.	-8-27-10	1.76 ± 0.21	0.53 ± 0.05	3.01 ± 0.21[c)]	QSYDMNVH	SGSESNIGANYVN
L-CDR3+1-opt.	-8-27-41	1.67 ± 0.16	0.49 ± 0.03	2.93 ± 0.27[d)]	QSYDMNVH	SGSESNIGNNYVQ

a) Affinity data of MS-GPC-8 are based on 8 different Fab-preparations which were measured on 4 different chips (2 x 500, 1000, 4000RU)

b) For MS-GPC-8-6 mean and standard deviation of 3 different preparations on 3 different chips (500, 4000, 3000RU) is shown.

c) 3000RU MHCII were immobilized on a CM5-chip. For each measurement 7 different concentrations from 1μM to 16nM were injected on the surface. Dissociation time: 150sec, regeneration was reached by 6μl 10mM Glycine pH2.3 followed by 8μl 7.5mM NaOH. For MS-GPC-8-6-19 mean and standard deviation of 4 different preparations are shown whereas for all other binders mean and standard deviation of 3 different preparations are shown.

d) One protein preparation is measured on 3 different chips (3000, 2800 and 6500RU).

e) Affinity determination of maturated MHCII binder on a 4000RU density chips; single measurement.

Molecular weights were determined after size exclusion chromatography and found 100% monomeric with the right molecular weight between 45 and 48 kDa.

Table 3a

Affinities of selected IgG$_4$ monoclonal antibodies constructed from F$_{ab}$'s. Errors represent standard deviations

Binder (IgG$_4$)	k$_{on}$ [M^{-1} s^{-1}] x10^5	k$_{off}$ [s^{-1}] x10^{-5}	K$_D$ [nM]
MS-GPC-8-27-41	1.1 ± 0.2	3.1 ± 0.4	0.31 ± 0.06
MS-GPC-8-6-13	0.7 ± 0.1	3.0 ± 1.0	0.50 ± 0.20
MS-GPC-8-10-57	0.7 ± 0.2	4.0 ± 1.0	0.60 ± 0.20

Table 3b

Affinities of binders obtained out of affinity maturation of CDR1 light chain optimisation following CDR3 heavy chain optimisation. Errors represent standard deviations

Binder (F$_{ab}$)	k$_{on}$ [M^{-1}s^{-1}] x10^5	k$_{off}$ [s^{-1}] x10^{-3}	K$_D$ [nM]
MS-GPC-8-6-2	1.20 ± 0.10	0.94 ± 0.07	7.6 ± 0.3
MS-GPC-8-6-19	1.10 ± 0.10	1.00 ± 0.20	9.0 ± 1.0
MS-GPC-8-6-27	1.80 ± 0.20	1.10 ± 0.20	6.3 ± 0.6
MS-GPC-8-6-45	1.20 ± 0.07	1.03 ± 0.04	8.6 ± 0.6
MS-GPC-8-6-13	1.90 ± 0.30	0.55 ± 0.05	3.0 ± 0.5
MS-GPC-8-6-47	2.00 ± 0.30	0.62 ± 0.04	3.2 ± 0.3
MS-GPC-8-10-57	1.70 ± 0.20	0.44 ± 0.06	2.7 ± 0.3
MS-GPC-8-27-7	1.70 ± 0.20	0.57 ± 0.07	3.3 ± 0.3
MS-GPC-8-27-10	1.80 ± 0.20	0.53 ± 0.05	3.0 ± 0.2
MS-GPC-8-27-41	1.70 ± 0.20	0.49 ± 0.03	2.9 ± 0.3

Table 3c

Binders obtained out of affinity maturation of GPC8 by CDR3 light chain optimisation

Binder (F_{ab})	k_{on} [M^{-1}s^{-1}] x10^5	k_{off} [s^{-1}] x10^{-3}	K_D [nM]
MS-GPC 8-18	1.06	8.30	78.3
MS-GPC 8-9	1.85	16.60	90.1
MS-GPC 8-1	1.93	20.90	108.0
MS-GPC 8-17	1.00	5.48	54.7
MS-GPC-8-6[a)]	1.20 ± 0.10	5.50 ± 0.70	8.0 ± 12.0

Chip density 4000RU MHCII

a) For MS-GPC-8-6 mean and standard deviation of 3 different preparations on 3 different chips (500, 4000, 3000RU) is shown.

Table 3d

Binders obtained out of HuCAL in scFv form and their converted Fabs

Binder	scF$_v$			F$_{ab}$		
	k_{on} [M^{-1}s^{-1}] x10^5	k_{off} [s^{-1}] x10^{-3}	K_D [nM]	k_{on} [M^{-1}s^{-1}] x10^5	k_{off} [s^{-1}] x10^{-3}	K_D [nM]
MS-GPC 1	0.413	61	1500	0.639	53	820
MS-GPC 6	0.435	200	4600	0.135	114	8470 (1 curve)
MS-GPC 8	0.114	76	560	0.99 +/- 0.40[b)]	29.0 +/- 8.4	346[a)] +/- 141
MS-GPC 10	0.187	180	9625	0.22	63	2860

Chip density 500RU MHCII

a) Affinity data of MS-GPC-8 are based on 8 different Fab-preparations which were measured on 4 different chips (2 x 500, 1000, 4000RU) and are shown with standard deviation.

b) Mean $\pm$ S.D. of three independent measurements.

Table 3e

Affinity improvements achieved by antibody optimization

mAb	Format	Optimization	k_{on} [s^{-1}M^{-1}] x 10^5	k_{off} [s^{-1}] x 10^{-3}	K_D [nM][a]
B8	Fab	parental	0.99 ± 0.4[b]	29.0 ± 8.4	346.1 ± 140.5
7BA	Fab	L-CDR3	0.96 ± 0.14	5.48 ± 0.73	58.6 ± 11.7
305D3	Fab	L-CDR3+1	1.90 ± 0.26	0.55 ± 0.05	2.96 ± 0.46
1C7277	Fab	L-CDR3+1	1.65 ± 0.21	0.44 ± 0.06	2.67 ± 0.25
1D09C3	Fab	L-CDR3+1	1.67 ± 0.16	0.49 ± 0.03	2.93 ± 0.27
305D3	IgG$_4$	L-CDR3+1	0.71 ± 1.6	0.33 ± 1.0	0.5 ± 0.20
1C7277	IgG$_4$	L-CDR3+1	0.11 ± 2.0	0.31 ± 0.4	0.3 ± 0.06
1D09C3	IgG$_4$	L-CDR3+1	0.71 ± 1.2	0.41 ± 1.1	0.6 ± 0.20

a. Affinities were determined by BiaCore.

b. Mean ± S.D. of three independent measurements.

Table 4

Killing efficiency after 4 hour incubation of cells with cross-linked anti-HLA-DR antibody fragments, and maximum killing after 24 hour incubation

Cross-linked Fab fragment	Killing efficiency against GRANTA	Maximum killing against PRIESS
MS-GPC-1	+	+
MS-GPC-6	+	+
MS-GPC-8	+	+
MS-GPC-10	+	+
MS-GPC-8-6	++	++
MS-GPC-8-17	++	++
MS-GPC-8-6-13	+++	+++
MS-GPC-8-10-57	+++	+++
MS-GPC-8-27-41	+++	+++

Table 5

Killing efficiency of anti-HLA-DR IgG antibodies of human composition compared to murine anti-HLA-DR antibodies against a panel of lymphoid tumor cell lines.

| Cell Lines | | | HLA-DR expression[a] MFL | % Killing by mAb[b] | | | | | |
| | | | | Murine mAbs | | Human mAbs | | | |
Name	DR type	Tumor Type	L243	L243	8D1	B8	1D09C3	1C7277	305D3
LG-2	1, 1	B-lymphoblastoid	458	79	85	86	87	88	82
PRIESS	4, 4	B-lymphoblastoid	621	87	83	85	88	93	74
ARH-77	12	B-lymphoblastoid	301	88	73	84	85	88	87
GRANTA-519	2, 11	B cell non-Hodgkin	1465	83	56	76	78	78	73
KARPAS-422	2, 4	B cell non-Hodgkin	211	25	32	51	66	68	71
KARPAS-299	1, 2	T cell non-Hodgkin	798	78	25	81	82	79	76
DOHH-2	1, 2	B cell lymphoma	444	29	23	58	59	60	53
SR-786	1, 2	T cell lymphoma	142	3	8	1	53	44	26
MHH-CALL-4	1, 2	B-ALL	348	35	41	43	63	46	43
MN-60	10, 13	B-ALL	1120	46	22	71	69	66	67
BJAB	12, 13	Burkitt lymph.	338	53	59	49	71	67	64
RAJI	10, 17	Burkitt lymph.	617	69	64	81	84	86	83
L-428	12	Hodgkin's lymph.	244	82	81	82	91	91	92
HDLM-2		Hodgkin's lymph.	326	77	73	89	88	84	90
HD-MY-Z		Hodgkin's lymph.	79	35	39	49	69	57	72

TABLE

KM-H2		Hodgkin's lymph.	619	81	56	75	86	88	87
L1236		Hodgkin's lymph.	41	52	62	44	63	66	66
BONNA-12		hairy cell leuk.	2431	92	91	91	92	91	86
HC-1		hairy cell leuk.	372	88	89	89	93	86	93
NALM-1	1, 4	CML	1078	44	4	83	82	78	65
L-363		plasma cell leu.	49	6	5	26	26	24	19
EOL-1		AML (eosinophil)	536	22	13	36	69	49	53
LP-1		multiple myeloma	315	12	0	61	73	70	73
RPMI-8226		multiple myeloma	19	6	0	14	29	26	19
MHH-PREB-1		B cell non-Hodgkin	175	3	3	2	4	8	11
MHH-CALL-2		B cell precursor leu.	+	5	5				
OPM-2		multiple myeloma	3	13	0	8	1	4	5
KASUMI-1		AML	5	0	0	8	10	10	6
HL-60		AML	3	18	0	3	15	9	22
LAMA-84		CML	7	7	9	5	11	5	7

a. Expressed as mean fluorescence intensity after staning with FITC-labelled L243. Single determination or the average of 2 to 3 experiments per cell line.

b. Based on viable cell recovery after treatment with 200 nM murine or 50 nM human mAb at 37 C for 4h. Determined by light or fluorescence microscopic cell counting or FACS analysis, as described in Experimental protocol. Each number represents an average from 2 to 6 independent experiments.

Table 6

EC_{50} values for certain anti-HLA-DR antibody fragments of the invention in a cell-killing assay against lymphoid tumor cells. All EC_{50} refer to nanomolar concentrations of the bivalent agent (IgG or cross-linked Fab) such that values for cross-linked Fab and IgG forms can be compared.

Antibody fragment	Form	Cell line tested	EC_{50} of cell killing (nM) +/- SE for bivalent agent
MS-GPC-1	Fab	PRIESS	54 ± 14
MS-GPC-8	Fab	PRIESS	31 ± 9
MS-GPC-10	Fab	PRIESS	33 ± 5
MS-GPC-8-17	Fab	PRIESS	16 ± 4
MS-GPC-8-6-2	Fab	PRIESS	8 ± 2
MS-GPC-8-10-57	Fab	LG2	7.2
MS-GPC-8-27-41	Fab	LG2	7.2
MS-GPC-8-27-41	Fab	PRIESS	7.7
MS-GPC-8	IgG_4	PRIESS	8.3
MS-GPC-8-27-41	IgG_4	PRIESS	1.1 ± 0.1
MS-GPC-8-10-57	IgG_4	PRIESS	1.1 ± 0.2
MS-GPC-8-27-41	IgG_4	LG2	1.23 ± 0.2
MS-GPC-8-10-57	IgG_4	LG2	1.0 ± 0.1
8D1	mIgG	PRIESS	33
L243	mIgG	PRIESS	47

Table 7

IC$_{50}$ values for certain anti-HLA-DR antibody fragments of the invention in an assay to determine IL-2 secretion after antigen-specific stimulation of T-Hyb 1 cells. IC$_{50}$ for the IgG forms (bivalent) are represented as molar concentrations, while in order to provide easy comparison, IC$_{50}$s for the Fab forms (monovalent) are expressed in terms of half the concentration of the Fab to enable direct comparison to IgG forms.

Anti-HLA-DR antibody fragment	Form	IC$_{50}$ (IgG/nM) ((Fab)/2/nM)		Maximum inhibition(%)
		Mean	SE	
MS-GPC-8-10-57	IgG	0.31	0.01	100
MS-GPC-8-27-41	IgG	0.28	0.07	100
MS-GPC-8-6-13	IgG	0.42	0.06	100
MS-GPC-8-6-2	IgG	3.6	1.1	100
MS-GPC-8-6	IgG	6.7	2.0	100
MS-GPC-8	IgG	11.0	0.8	100
MS-GPC-8-6-2	Fab	4.7	1.9	100
MS-GPC-8-6-13	Fab	2.1	0.8	100
MS-GPC-8-6-19	Fab	5.3	0.2	100
MS-GPC-8-10-57	Fab	2.9	1.0	100
MS-GPC-8-6-27	Fab	3.0	1.2	100
MS-GPC-8-6-47	Fab	2.6	0.6	100
MS-GPC-8-27-7	Fab	5.9	2.2	100
MS-GPC-8-27-10	Fab	7.3	1.9	100
MS-GPC-8-27-41	Fab	3.6	0.7	100
MS-GPC-8-6	Fab	20		100
MS-GPC-8	Fab	110		100

Table 8

Antibody Name Conversion Table

MS-GPC-8	B8
MS-GPC-8-17	7BA
MS-GPC-8-6-13	305D3
MS-GPC-8-10-57	1C7277
MS-GPC-8-27-41	1D09C3
MS-GPC-1	17
MS-GPC-6	8A
MS-GPC-10	E6

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The following is a partial list of references cited in the instant application. The contects of these references are hereby incorporated herein by reference.

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